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ENVIRONMENTAL AWARENESS IN WIND POWER GENERATOR DEVELOPMENT

Case study ABB Oy

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ABSTRACT

Sustainable development has had an influence on decision making in companies during the past years. Businesses are aiming to reach a sustainable balance in the consumption of resources, and in the production of goods. In order to support sustainable growth, companies are paying more attention to green products, environmental friendly production processes and environmental aspects. National and international laws and other environmental requirements seem to be increasing in the future, and new guidelines are set for company reporting and performance.

The company case study was called out at ABB Oy Wind Power Generators Development. The aim in the research was to understand the level of environmental awareness and the documentation of environmental evaluation at the product development. In the development phase of the product, changes to affect the environmental impact of the product over its lifetime are at the highest. The information for the study was gained via an online company questionnaire and through a case study workshop. Also the customer’s viewpoint was studied with an online questionnaire, and results were analysed qualitatively as well as quantitatively.

Based on the research, the evaluation or at least documentation was found to be insufficient when compared to the requirements. The current checklist has not been used and it is not fully suitable to be used in the environmental evaluation of wind power generator development. According to the research, the engineering team required more information on the environmental aspects with regard to their own product group. Based on the survey, proven environmental design can be seen as a competitive advantage. This gives enough grounds to develop the environmental evaluation process in the engineering of wind power generators. The research noticed the importance of continuous improvement and follow-up.

On the grounds of this company study, a product specific environmental checklist was suggested for wind power generator projects. A long-term target to gain a proper understanding of the life cycle is needed to support decision making.

Keywords: Environmental Engineering, Environmental Impacts, Life Cycle Assessment, Life Cycle management, Sustainable Design, Sustainability, Wind power generators

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TIIVISTELMÄ

Kestävä kehitys on ohjannut yritysten päätöstentekoa viime vuosina enenevässä määrin. Yritykset pyrkivät löytämään kestävän kehityksen tasapainon kulutettavien luonnonvarojen ja raaka-aineiden käytössä tuotteiden valmistukseen. Kestävän kehityksen strategioita ja raportointia on lisätty monissa yrityksissä ja tuotteen elinkaaren aikaisia vaikutuksia on pyritty ymmärtämään tuotteen elinkaarianalyysin avulla. Myös kansallisten ja kansainvälisten lakien ja ohjeiden uskotaan tiukentavan tulevaisuuden ympäristövaatimuksia ja lisäävän yritysten raportointi- ja tiedotusvastuuta.

Yritystutkimus tehtiin ABB Oy:n Tuulivoimageneraattorit tuotekehityksessä ja suunnittelussa. Tutkimuksen päätarkoituksena oli ymmärtää, millaisella tasolla ympäristötietoisuus ja siihen liittyvä dokumentointi on tuotesuunnittelussa. Koska tuotekehityksessä uskotaan olevan suurimmat vaikutusmahdollisuudet tuotteen ympäristövaikutuksiin sen koko elinkaaren aikana, kohderyhmäksi valikoitui tuotesuunnittelu. Tutkimus tehtiin sähköisesti toteutetun kyselytutkimuksen ja ryhmätyön avulla. Myös asiakkaiden näkökulmaa ympäristöasioista ja -vaatimuksista selvitettiin sähköisesti toteutetulla kyselyllä ja tulokset analysoitiin kvantitatiivisesti ja kvalitatiivisesti.

Tutkimuksessa selvisi, että raportointi suunnittelun aikaisten ympäristönäkökohtien tarkastelusta on puutteellista. Olemassa oleva tarkastuslista ympäristönäkökohdista ei sovellu tuulivoimageneraattoreiden suunnitteluprosessiin. Tutkimustulosten perusteella sekä työntekijät että asiakkaat uskoivat ympäristövaatimusten kasvavan tulevaisuudessa. Kun samaan aikaan ympäristöystävällisen tuotteen uskottiin olevan kilpailuvaltti, ympäristönäkökulmat paremmin huomioonottavan ja dokumentoivan suunnitteluprosessin kehittämiselle on vahvat perusteet.

Tutkimustulokset korostavat jatkuvan seurannan tärkeyttä. Tämän johdosta tuulivoimageneraattoreiden käyttöön esitettiin tuotespesifisempää ympäristönäkökohtien tarkastuslistaa sekä siihen liittyvää tukimateriaalia. Pidemmällä tähtäimellä suositeltiin elinkaarianalyysin tekemistä, sillä sen avulla kriittisiä tarkastelupisteitä voidaan helpommin nostaa suunnittelun tietoisuuteen.

Asiasanat: Elinkaarianalyysi, Kestävä kehitys, Tuotekehitys, Tuulivoima-generaattorit, Ympäristötietoisuus, Ympäristövaikutukset

CONTENTS

1 INTRODUCTION

Sustainability has become imperative and a trend word in today's business life. Many companies are publishing sustainability data and figures and hold different environmental standards, certificates and award nominations for their activities towards a sustainable future. The current way of living requires more resources than our globe can afford. In business life, sustainability means that a company takes into account all three following dimensions of sustainability in its operations: the economic, the social and the environmental aspect (UNEP, p. 10). Products and services are prepared in a way that tomorrow's resources will not be used in advance.

A common concern of the threat of global warming has increased the awareness of environmentally friendly production methods and materials in order to reach the target of limiting the mean temperature rise to a maximum of 2º C degrees by the year 2100 compared to pre-industrial times. Different industries play a significant role in reducing greenhouse gases. 18 % of the greenhouse gases come from manufacturing industries, and on the whole, the energy sector is responsible for 78 % of the greenhouse gases (OSF b, 2014). Moreover, the waste management of manufacturing industries is a significant factor in coping with climate change. In Finland alone, 98 million tonnes of waste was produced in 2013, from which 6115 tonnes (9.3 %) came from manufacturing industries (OSF b, 2014).

The demand for electricity is also growing fast. According to statistics, 23 536 terawatt-hours was generated in 2014 (BP a, 2015 p.2). The global demand for electricity is projected to increase by 37 %, having an average annual growth rate of 1.1 % on planned policies (BP b, 2015, p.1). At the same time ambitious targets are set to limit the temperature rise to a maximum 2º C, which generates the need for energy-saving products, produced in a sustainable way.

Even though growth has not been as fast as over the previous decades, it is still significant. It is estimated that there will be 1.4 billion electricity users more in the world by 2035, which means 8.7 billion people needing electricity instead of the current 7.3 billion people. The growth in electricity demand is dominating in China and India instead of the OECD countries. Also, economic growth means that the demand for electricity will rise. Carbon emissions from energy consumption are also projected to increase at an annual rate of 1%, meaning in total a 25 % increase in carbon emissions originating from energy consumption 2013 – 2035. (BP c, 2015 p. 9 - 11). Tackling the increase in electricity demand and the increase in carbon emissions, renewable sources of energy are forecasted to produce 8 % of the total energy demand in 2035. Today, only 3 % of energy consumption is met with renewables (BP b, 2015, p.1).

The common concern of global warming, resource-conscious consumers, and respect towards bio-diversity, moral responsibility and commitment to operate according to tightened acts and decrees on the environmental area, are the key drivers for companies developing better practices in the area of sustainability. Many companies have noticed that environmental activities may not necessarily cost more but can actually save money when energy, waste management and the use of resources are planned on the “less is more” principle. Also, many businesses that demonstrate environmentally friendly, eco-efficient activities may have a competitive advantage. Customer expectations towards proven environmental and sustainable performance are increasing.

A vast amount of companies’ marketing materials show a nice image of being environmentally friendly. While processes are externally and internally audited, and the environmental performance is reviewed on a daily level, many companies still lack the proven evidence of their environmental performance. The demand for having measured data, check-lists or other type of material for witnessing that environmental issues are taken into account already from the very beginning of a product’s lifetime, has raised the need for a research at Wind Power Generator R&D and Engineering at ABB. Recently, the customer base has been showing more attention towards environmentally friendly processes and products. ABB's strategy identifies environmental concerns as a key driver for market growth and a significant proportion of ABB's revenues come from products that increase customers' energy efficiency. These core matters are driving towards the need to increase environmental awareness in general and testified performance in environmental evaluation of product development.

In this research, the main drivers will be to increase environmental awareness in wind power generator engineering and R&D operations, so that customer expectations can be met and documented better for future demand. Also, one target is to achieve better tools to be able to answer different types of customer questions in the future with respect to environmental and lifetime issues of wind power generators. ABB states on its website that sustainability considerations cover how its products are designed and manufactured in the main description of sustainability (ABB 2015). That company declaration gives a good starting point to this research in order to concentrate on how environmental aspects can be taken into consideration in engineering in reality. Even though sustainability has also other dimensions rather than just environmental considerations, this research will be concentrating on environmental performance. This is also due to the lack of detailed information on how to conduct social and economic assessments in an organization, where the environmental aspect of sustainability can be covered better with methodology, such as Life Cycle Assessment (UNEP c, 2015, p. 23).

First, in this research, ABB Company is introduced as well as wind power generators, and, consequently, the production process of the generators. The company, its product and the process presentation will be followed by a more generic overview of sustainability, environmental performance and life cycle management from a manufacturing industry perspective. Qualitative research with its results will be introduced in the following chapters.

A research questionnaire has been made both externally for ABB customers and internally for the development team. Based on the analysed results, a framework has been defined and new materials and an action plan to increase the environmental awareness and product’s environmental evaluation in the engineering phase has been created.

Sustainability is also a state of mind, and an essential part of a company’s corporate management, quality and the environmental management system. This means a cross-organizational approach is needed. A significant part of the research was to collect the experiences and the expectations from different stakeholders.

1.1 Background

During the past two years, the amount of environmental inquiries in wind power generator sales from the customers has been increasing. Also, the extent of the questionnaires is wider than before. It is evident that customers have started paying more attention to environmental aspects in the products and in the production process of the products (wind power generators) they are purchasing. At the same time, it has been recognized that there are not enough supportive materials available for replying to those questionnaires, even though in general ABB has been taking big steps towards sustainability in order to meet regulations, for example, the REACH and ROCH lists as well as all company policies in the area of sustainability. ABB has received, as the first certified electric equipment manufacturer in Finland, the Environmental Certification 14001 from the year 1996 onwards.

Even though there is a proposed way to evaluate the environmental aspects of the products during the product development and engineering project, mainly by using checklists, this has not been utilized in wind generator development and research.

1.2 Aim of the research

The main research question in this thesis was the quality and quantity of current environmental evaluations in wind power generator products, and if they are advanced enough to answer to the customer expectations. The focus was on studying if processes support the consideration of environmental aspects during their development, engineering, and project management.

The main target of this research was to understand why the proposed way of evaluating environmental aspects of a product is not functioning, and why checklists are not used during the projects. This means there is no evidence to be presented internally or externally.

As a result of this study, the target was to issue a proposal for supportive materials and methods, on how taking the environmental perspective into consideration in wind generator development and engineering could be secured. A proposal for increasing environmental awareness in the organization was presented as an outcome. The documentation of good quality support in proving environmental aspects has been taken seriously during the engineering phase of the product. As a result, better documentation can be utilized in customer audits, and other stakeholder communications later.

1.3 Research methods

The comprehensive view of the current status was modelled by observations. The researcher of this study is working in a company in a stakeholder organization, which helped in forming the view of the status. Additional background information was collected by short interviews and by reviewing the company instructions, process descriptions, and project files. The customer’s interest towards environmental aspects was also charted by collecting all environmental inquiries from the customer field sent to

ABB within the past three years and reading customer companies' sustainability reports or other co-ordinative data available publicly on the customer web-site.

In this study, stakeholders were first involved (designing engineers, product managers, customers, and suppliers) in order to chart how much environmentalism means in this product category. Also, by means of qualitative research workshops and questionnaires, the level of current information and the knowledge available was studied in order to define the correct level of future supportive materials and methods. The qualitative research with its findings is reported in the main Chapter Six (6).

In the final stage of this research, a suggestion was created on how environmental performance, especially during engineering and R&D, can be secured and documented as an important phase of product development. This research can help also the organization in fulfilling the requirements imposed by the ISO14001:2004 Environmental Management Standard for continuous improvement in environmental objectives. Increased maturity of environmental management can be reached by improvements in the process and in the environmental performance as well as with help of the mind-set change inside the organization.

2 ABB PRESENTATION

ABB is a global company manufacturing automation products, robotics, power electronics, motors and generators, as well as power distribution systems, just to mention a few, for various industrial purposes. ABB's boilerplate tells this as follows:

> *ABB (www.abb.com) is a leader in power and automation technologies that enable utility, industry, and transport and infrastructure customers to improve their performance while lowering environmental impact. The ABB Group of companies operates in roughly 100 countries and employs about 140,000 people, of whom around 5,200 in Finland. (ABB 2015).*
>
> *As one of the world's leading engineering companies, we help our customers to use electrical power efficiently, to increase industrial productivity and to lower environmental impact in a sustainable way (ABB VISION).*

Even the official short description of the company manages to deliver the key message and a vision for lowering environmental impacts, operating in a sustainable way, and manufacturing products that help others to do the same. ABB invests annually over 1.5 billion USD in development (4 - 5 % of total revenue, and the revenue was 40 billion USD in 2014). Over 8 000 scientists and engineers work for development and research of technologies and products. (ABB 2015). In addition to that, thousands of engineers globally attend valuable product development workshops. The latest sustainable innovations at ABB are in further development of solar inverters, new wind generator products, electric vehicles, and fast-charging stations for electric cars. Besides the products, ABB offers life-cycle services that help customers to reach their targets in productivity, efficiency and environmental performance.

ABB employs 140 000 people in over 100 countries (ABB 2015). Global presence, diverse products and continuously changing legislation sets pressures on world class operations, also with respect to environmental performance. Global manufacturing means also global transportation of products and materials.

2.1 Divisions at ABB

ABB is divided into five divisions: Power Products, Power Systems, Discrete Automation and Motion, Low Voltage Product and Process Automation, as shown in Figure 1. This research will concentrate on one of the product groups, Generators (and specifically wind power generators), which is part of the Discrete Automation and Motion Division at ABB.

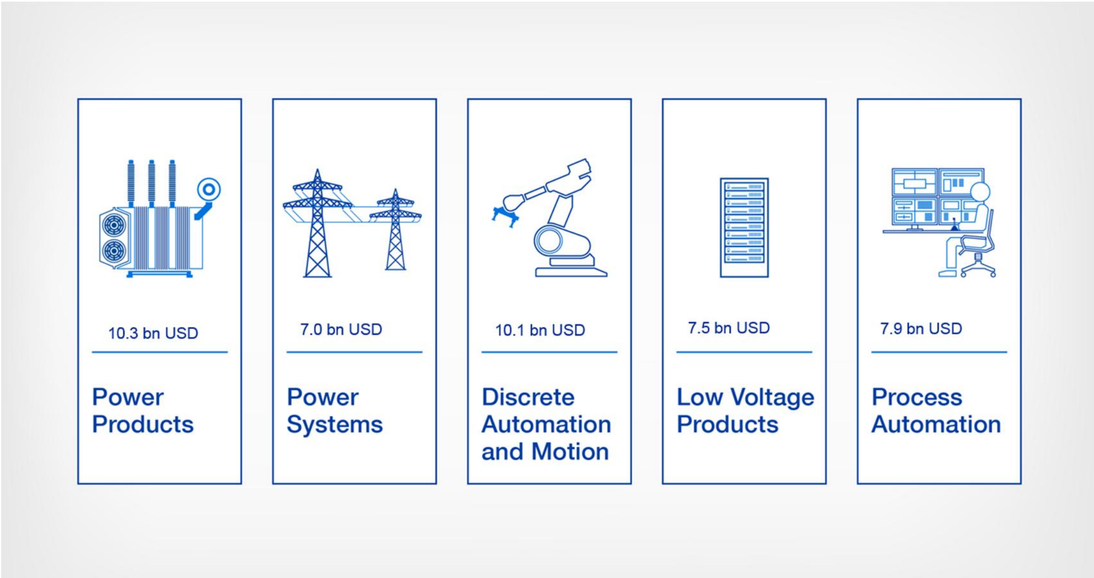

Figure 1. Five divisions at ABB. (ABB 2015).

In the Discrete Automation and Motion Division is working 30 000 employees globally, and product variation inside the division is extensive. The Discrete Automation and Motion (DM) Division offers a wide range of products such as drives, motors, generators, power electronics systems, photovoltaic inverters, programmable and robots. These products help customers to improve their productivity, save energy, improve quality, and generate energy.

Each division is further divided into Business Units (BUs). In the Discrete Automation and Motion Division, there exist four different business units: BU Drives and Controls, BU Motors and Generators, BU Power Conversion and BU Robotics. Business units are shown in Figure 2. In the Figure 2, Business Unit Motors and Generators is highlighted, since this research is concentrating on one specific product group, generators belonging to the Motors and Generators Division at ABB.

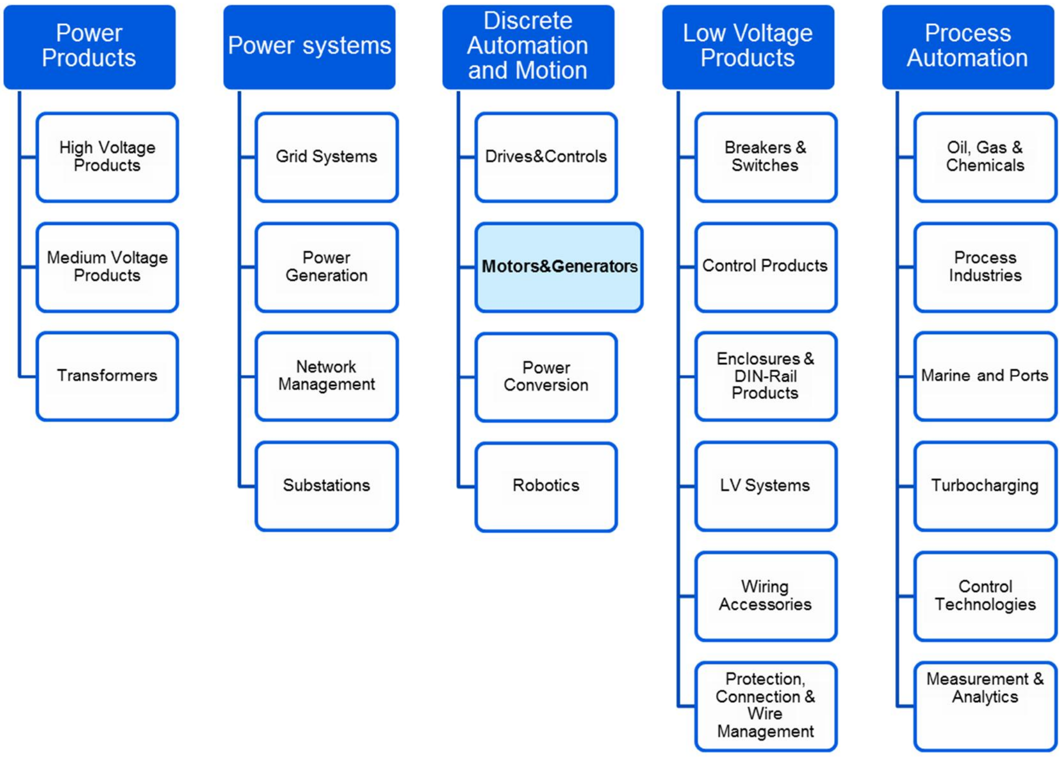

Figure 2. Business Units in main Divisions at ABB. (ABB 2015).

2.1.1 Product Group Generators

Rotating electrical machines needed in power production are designed and manufactured in the product group Generators. The product group Generators manufactures generators for wind turbines, steam and gas turbines, as well as for diesel and gas engines. Additionally, product group for generators provides generators for railway and marine applications, for geothermal energy and for solar thermal power purposes, as well as for synchronous condensers and energy recovery expanders. The aim of the product group is to provide products that help customers to save energy while at the same time generating it, and to be productive and sustainable throughout the product's lifetime. The product groups inside the Motors and Generators Divisions are shown below in Figure 3.

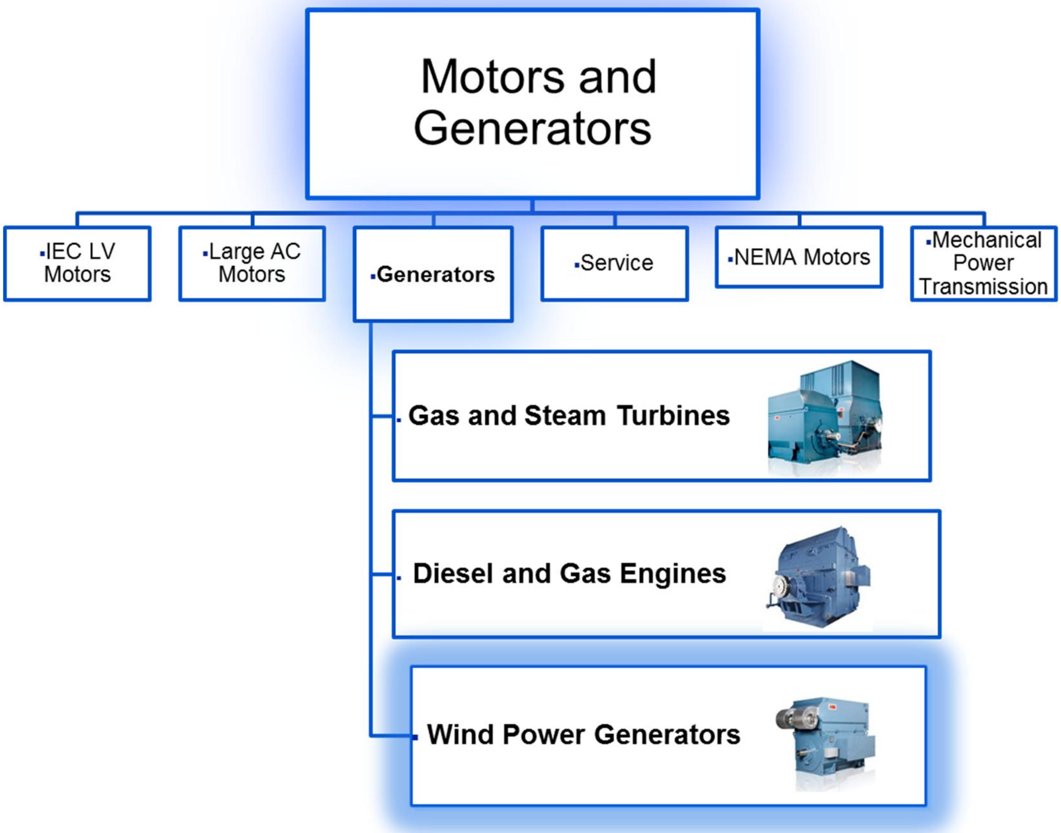

Figure 3. Product groups in the Motors and Generators Division at ABB. (ABB 2015).

Product group of generators has 45 factories around the world. Wind power generator manufacturing are centered in the Estonian, Indian, Chinese, and Brazilian factories. The Development and research functions (R&D), sales, engineering and sourcing activities are operating globally. Efficient processes secure world class operations on a global scale. Currently, an installed base of ABB generators of over 100 GW is producing energy continuously for over 50 GWh every hour worldwide, providing energy for 140 million people throughout the year (ABB 2015).

During this research, ABB announced the merger of two Product Groups: Large AC Motors and Generators, effective from 1.10.2015. This merger did not affect the context of this work. For future utilization, the knowledge, information, and improvement ideas can be exploited in the new merged

Product Group. Also, the change in the organization from five to four main divisions is going to take place from the beginning of the year 2016.

2.1.2 Wind Power Generators

ABB has manufactured over 35 000 wind generators within past 30 years to become the world's leading wind turbine manufacturer (ABB 2015). In the green energy field, environmental performance over the whole product's lifetime receives a higher emphasis compared to some other products. This sets the target for this research when aiming to find solutions, on how environmental issues could be taken into account even better in development and research, as well as in engineering phases. Also, customer requirements and international standards will be taken into account is this study, since those form the baseline for the the environmental requirements. A documentation and a recording of the data is an essential tool for an improvement but it also supports in the customer communication.

Wind power generators are rotating electrical machines used inside wind turbines in order to transfer kinetic energy from the wind into electrical power, electricity. Wind power is a clean form of energy creating no direct emissions or contamination while producing electricity. Because generating emission-free power, the wind turbine manufacturers have been keen on studying the environmental impacts of turbines over the whole life cycle from the manufacturing phase of the turbines and the components inside, including the transportation, installation, start-up and maintenance, and in the end, in the dismantling, disposal and recycling of the materials (Martinez 2009, p. 667). This interest in monitoring the key components from the point of view of life cycle assessment, puts pressure on component suppliers to review their own processes from an environmental perspective.

Conditions such as wind speed, site altitude and climatic conditions can vary at each customer site. Generators are designed according to the requirements and the specifications of individual customers. ABB has solutions for all wind speeds and all main drivetrain concepts of a wind turbine.

3 WIND POWER GENERATOR MANUFACTURING PROCESS AND MATERIALS

In this chapter, the wind power generator manufacturing process and main materials will be presented. Many materials and chemicals are needed during the manufacturing process. A typical wind power generator weights approximately 10,000 kg, but depending on the type of the generator specified by the customer, the weight can vary between 5 000 kg to 65 000 kg. This means, a lot of materials are needed in the production. The bigger the machine, the more emphasis have to be placed on transportation and packaging, which will have an effect on the total cost and environmental impact. This is one essential research area in a green product manufacturing, especially in a global business. Components and raw materials are typically sourced worldwide and not always utilizing the nearest alternative source. This brings challenges in the monitoring the whole supply chain also from a sustainability point of view.

For the most part, the materials needed to build a generator are steel, electrical steel, copper and insulation materials. Additional electrical components, chemicals (for example epoxy resin in vacuum impregnation process), paint, lubrication, and anti-corrosion protection tectyl are needed in the manufacturing process. The consumption of the materials is not limited to the manufacturing of the product itself but also to the packing. Transportation distance for ready products can be from one continent to another, so there needs to be considerations in place for packaging. If the packaging is too light, there is a real chance it will not arrive in good condition, especially in overseas deliveries.

Figure 4 shows an example of an ABB wind generator.

Figure 4. Doubly-fed wind power generator from ABB (ABB 2015.)

In this chapter, the wind generator manufacturing process and materials will be presented. This gives the background information for ways to affect the products eco-efficiency during the product's lifetime.

3.1 Materials used in wind power generators

A remarkable share of a wind generator's direct cost comes from its materials. Although manufacturing in the production line takes several days and up to hundreds of man hours and machine hours, the majority of the costs come from the direct materials.

Figure 5 shows an exploded view of a wind generator and the materials of a typical wind power generator are shown in Table 1. Main parts of a wind generator are the rotating part of the generator, rotor, and the stationary part of the generator, the stator. The shaft in the rotor assembly transmits the power.

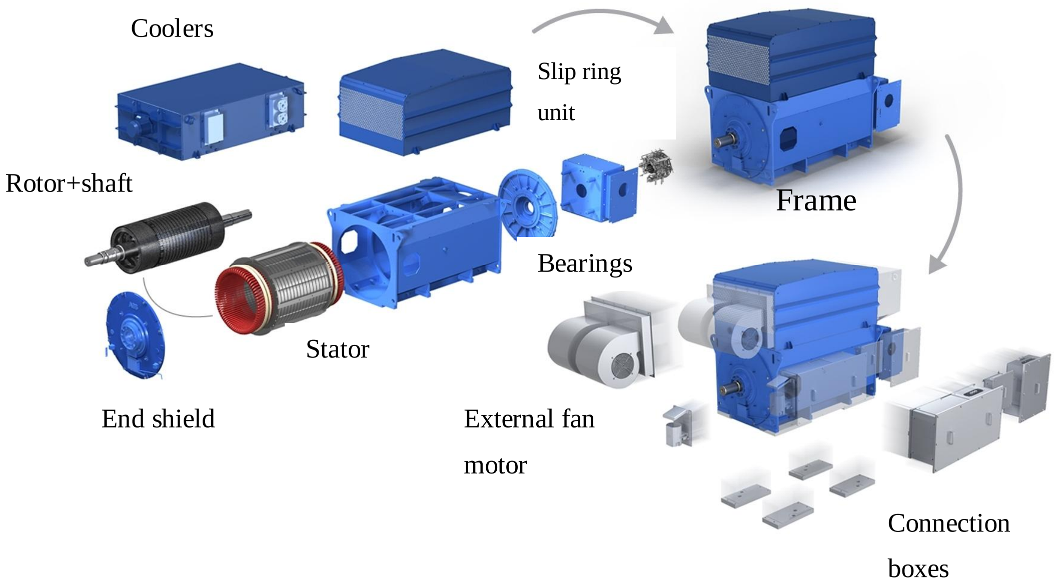

Figure 5. The main components inside a typical wind generator (ABB 2015).

Table 1. The main material in a typical wind power generator based on material weights in the machine. (ABB 2015).

Main Materials in typical Wind generator	Percentage share
Steel/electrical steel	74 - 83 %
Copper	10 – 15 %
Cast Iron	1 – 2 %
Aluminium	0 – 1 %
Insulation materials, plastics, rubber etc.	1 – 2 %
Stainless steel	less than 1 %
Other	less than 1 %
If permanent magnet machine additionally Magnetic materi-als:	
Magnetic materials	1 – 4 %

In a typical wind power generator, the amount of copper is approximately 1 000 kg – 1 500 kg. Figure 6 illustrates the remarkable share of recyclable materials, steel and copper, in a wind power generator.

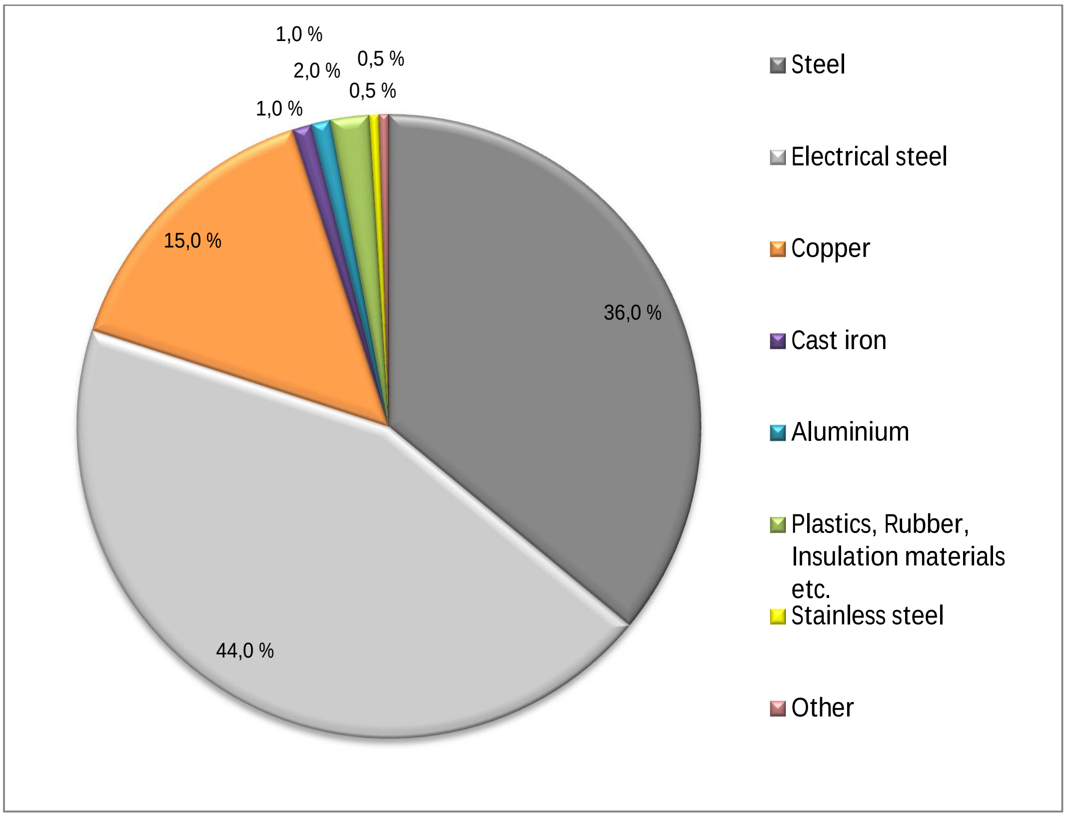

Figure 6. The main material percentage shares (of the total weight) in a typical wind power generator. (Figure adapted from information received from ABB, 2015).

3.2 Manufacturing process

The manufacturing process of a wind power generator contains several work phases. Contrary to many other industries, the manufacturing of an electrical machine of this size and character also requires some manual work phases. As a result, employee occupational health and safety is in high focus in the company policies and in the training programs.

The manufacturing process can be categorized by five main process steps, shown in Figure 7.

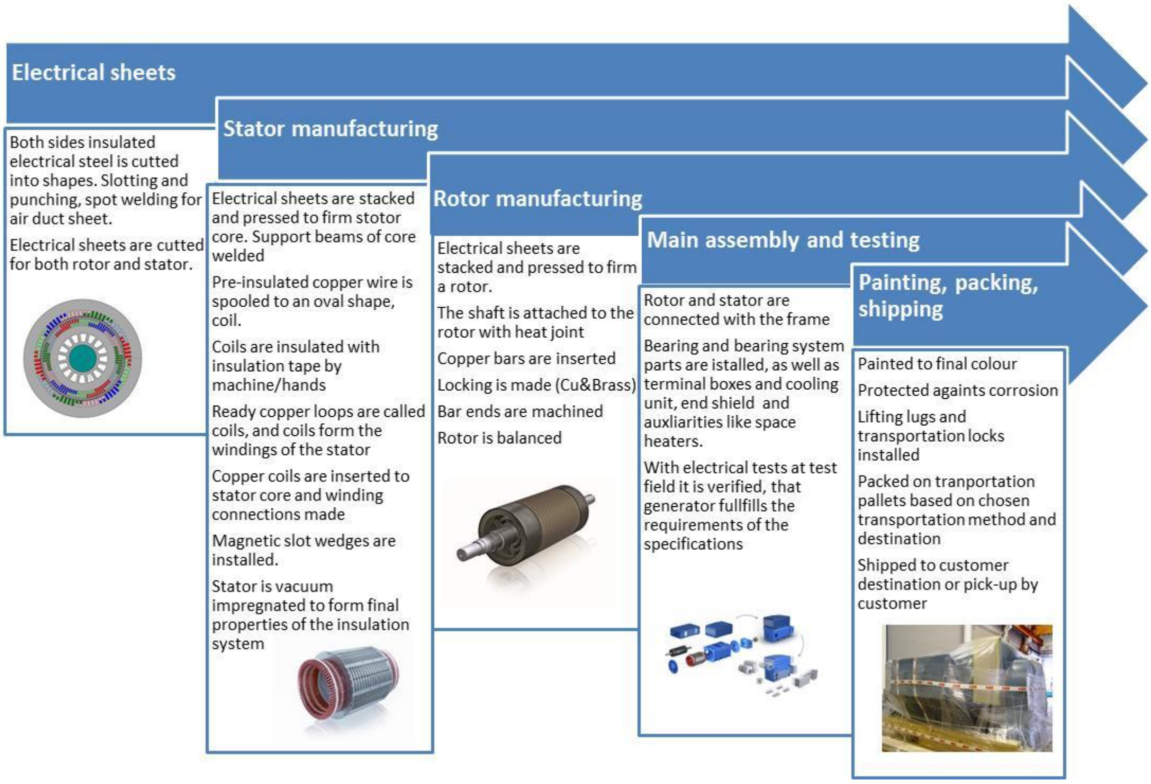

Figure 7. The main production process steps of an ABB wind power generator (Figure adapted from information received from ABB, 2015).

3.2.1 Phase 1 – Electrical sheets

Electrical sheets are needed in the manufacturing of both the rotor and the stator. Electrical steel used for a wind power generator is insulated steel, which is insulated on both sides. This type of thin (0.5 mm) insulated electrical steel is purchased for the production factories in rolls of different widths and cut to correct shapes in the machine cutting phase. The electrical steel is cut to the required shape, round shapes or segments depending on the product type, and the diameter of the ready rotor and stator. Cutting of the main shape and shaft hole is called punching. Additionally, sheets are slotted, since in the next phase, slots are needed for adding copper coils to the structure. Also, air ducts are needed for the internal air circulation to make sure that copper windings do not get too warm.

3.2.2 Phase 2 - Stator manufacturing

Electrical steel sheets which have been cut are called laminations. In the stator manufacturing phase, laminations are pressed together between thicker end plates, forming a strong structure for the stator core. When a pressed stator core is ready, support steel beams are welded onto the outer core.

The second main component in a stator is the stator winding. Stator windings are made of copper coils which have been wound in form. The copper is purchased as an insulated copper wire and it is processed in a winding factory to a correct shape and a structure. Ready-made copper shapes used in the stator structures are called stator coils or stator windings.

In a spooling machine, the insulated copper gets an oval shape. An additional insulation taping is added by machine and/or by hand. The level and the style of the insulation is dependent on the product type. The insulation materials are chosen to fulfil the insulation class requirements. A spooled loop shape can be spread into a correct shape, to be able to later fit the stator coils into the lamination slots. Coil manufacturing always takes place in the production space, where temperature and humidity can be monitored and controlled. The type of the winding insulation, the qualification, the design and the acceptance test of the insulation system is designed based on the IEC 60034-18 standard. After the stator core has been stacked and pressed, ready coils are inserted into the stator slots. Also, magnetic slot wedges (if used in a generator design) are mounted onto the slots before the generator is ready to be impregnated.

When the stator's main structure is ready, the next step in stator manufacturing is a process called vacuum pressure impregnation (VPI). This is a process where the stator is impregnated with a high quality epoxy resin in order to create the final properties of the insulation system: Mechanical strength, dielectric durability capabilities, moisture and contaminant resistance as well as the thermal conductivity. In the vacuum impregnation process, the stator is preheated in an oven, and then put into a preheated, epoxy resin-filled tank, from which air is pumped out to create a vacuum environment. Soft insulation materials are hardened in the process and a pressure is created in order to maximize the penetration of the resin thoroughly in the whole the insulation system.

After impregnation, the stator is removed from the tank and placed into an oven to be heated before the resin curing. The parameters which are controlled during the impregnation process are the viscosity of the epoxy resin, the temperature and the process time. The epoxy resin is a chemical that can be dangerous to humans, so special attention on an occupational safety needs to be paid in this phase.

3.2.3 Phase 3 - Rotor manufacturing

The rotor can be manufactured at the same time as the stator. The rotor core, like the stator core, is built from electrical steel laminations similarly by stacking and pressing the steel sheets. The shaft is attached to the rotor by a heat joint, where the rotor package is heated up to 250 – 280 ºC and the shaft inserted into the stator. The shaft is made from solid hot rolled structural steel. The rotor winding is made from copper bars. Rotor bars are installed and the locking is made by a copper and brass joint, and edges of the bars are machined. If the generator is a permanent magnetic generator, magnetic materials are also needed, typically a mixture from Neodymium (NdFeB), Dysprosium (Dy) and Terbium (Tb) combined with different fillings and binder compounds.

3.2.4 Phase 4 - Main Assembly and factory acceptance testing

In the main assembly, the rotor and the stator are connected with the frame, end shields and auxiliaries. The bearings and parts of the bearing system are installed, the terminal boxes, as well as the cooling unit and auxiliaries in the same manner as space heaters. For bearing installation, the bearing needs to be heated.

Before the finished product is allowed to leave the factory, the so-called factory acceptance tests need to be conducted, in order to make sure the product fulfils the necessary requirements of the specifications. These tests are made according to ABB standards as well as those of IEC 60034, which include tests such as the measuring of insulation resistances, a vibration measurement, as well as various short circuit and high voltage tests.

3.2.5 Phase 5 - Painting, packing and shipping

The generator is returned from the test field to the factory paint shop to be painted to a final colour after the factory acceptance tests. The paint class and the colour are defined by the customer. Also, parts that could get rusty during the transportation and the warehousing are protected with an anti-corrosion paste tectyl. The generator is ready to be shipped after the installation of the transportation supports and after a proper packing.

3.2.6 Life cycle phases of the wind power generator

The knowledge of the product's life cycle phases outside the actual production process is similarly essential information, when making life cycle assessments. The product should be designed so that it is resource-conscious, easy to manufacture, and that components for the product can be maintained and repaired.

The wind power generator consists of mechanical and electrical components, but the majority of the components are from fully recyclable materials such as copper and steel. It is challenging to collect information on all the sub-components all the way down to the raw materials level. As stated in the life-cycle assessment of a multi-megawatt wind turbine (Martinez 2009 p. 672), the majority of the environmental impacts of the wind turbine result from the foundation. The environmental impact of the nacelle is the lowest of the main components of a turbine. But according to the research, copper has the highest environmental impact due to the high value of the metal (Martinez 2009, p. 672). A relatively high amount of that copper is inside the generator. A typical generator design contains about 1 000 – 1 500 kg of copper. According to Martinez's research, copper amounts should be reduced or replaced by other materials in order to lower the environmental impact of the nacelle (Martinez 2009, p. 672).

Aluminium has approximately similar performance characteristics and it would have a lower environmental impact. However, reaching required efficiencies and other customer required performance values, has restricted the replacement of copper with aluminium windings. Copper has suitable electricity and heat conductive characteristics needed in the generators. The advantage of copper is that it has a high recycling value which lead to high recycling realization with low losses (Martinez 2009, p. 669).

Some generator types include also magnetic, rare earth materials like Neodymium (NdFeB), Dysprosium (Dy) and Terbium (Tb). The total amount of magnetic materials can vary from some 100 kilograms to 3 000 kilograms (ABB 2015) depending on the generator concept. The amount of the actual rare earth materials in the magnets are lower, since in order to create optimal magnetic characteristics, other compounds need to be used as filling materials. From the total weight of the magnets, typically some 28 – 45 % of the weight comes from rare earth materials. In magnets, it is essential to choose a reliable magnet supplier. The filling materials of the magnets can also cause a risk from an environmental point of view. Since the amount of rare earth materials is limited, recycling of the materials should be secured.

Figure 8 shows the life cycle of a wind power generator according to the life cycle assessment philosophy.

Figure 8. Life cycle of a wind turbine generator (Figure created according to information and images received from ABB).

3.3 Project gate model

Any new product development at ABB goes through utilizing ABB's Gate Model for the Technology Development, officially referred to as the Product- and System Development Model. Depending on the project, the amount of decision gates has been predefined by a gate steering committee. This gate model ensures that all process objectives, such as the time schedule, the resources, the risks, the possibilities, the financial aspect, as well as the environmental, health and safety aspects are considered every time a product is developed and introduced to the markets. The systematic evaluation and the decision making process aims to be an efficient tool for fact-based decision making, and an attempt is made to minimize time to market and costs for poor quality. The gate model principle is shown in Figure 9.

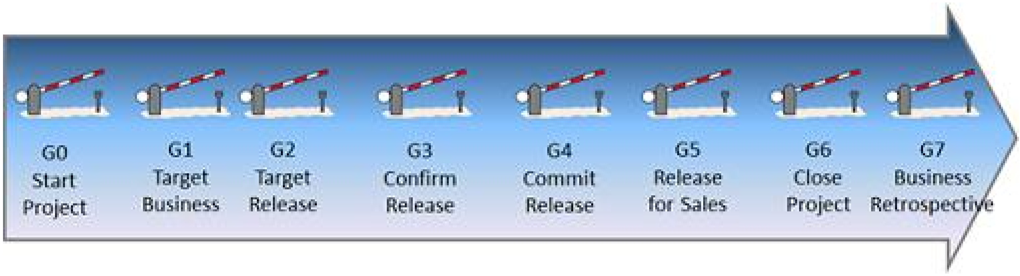

Figure 9. ABB Gate Model (ABB 2015).

3.3.1 Environmental questions in the ABB Gate Model

The problem with ABB's current Gate Model check list is, that even though there are questions regarding environmental objectives, some users have had difficulties in identifying what kind of an environmental performance review is expected. The scope and the extent of the environmental performance check during a project phase and in the engineering have not been totally clear. Especially in wind power generators, this information is essential due to increasing customer requirements. It can be also defined as a continuous improvement process in order to be able to answer better to customer requirements for sustainable performance, the authority demands, as well as ABB's internal targets to minimize the environmental footprint of its products and processes.

Before entering further to a product development project, the idea is evaluated based on pre-defined criteria from the technical and commercial perspectives. During Gate 0, a prestudy is made and the initial data is described when making a proposal for a project. In Gate 1, the scope of the project is defined and agreed upon. Gate 1 includes an official checklist where the first environment and health&safety related question can be found. The first environmental question in the Gate 1 project checklist refers to a separate checklist on environmental and health as well as safety related matters:

> G1Q15: Identify risks for environment and health & safety. Use the checklist on http://inside.abb.com/sustainability under ABB's Sustainability toolbox/Product development.

The health and safety as well as environmental checklist are located in the ABB Intranet, so it is not an integral part of the project’s main checklist. That might be one of the reasons, why it has not been used more widely. One of the research questions was, whether something in the process hinders the use of the environmental checklist.

When moving forward in the project, the next phase is Gate G2, where an agreement to start a project execution is made. Again, the project checklist to evaluate possible risk and other business objectives is completed according to internal group instructions. Every gate has an owner, and if tasks are not thoroughly studied, the gate owner has the responsibility to require a re-doing the gate or to ask the project team to provide further information. However, an incomplete checklist on environmental issues has so far never been an obstacle to proceeding. In Gate 2, the environmental question is as follows:

G2Q26: Identify risks for environment and health & safety. Use the checklist on http://inside.abb.com/sustainability under ABB's Sustainability toolbox/Product development.

When the project and the product development are proceeding, at Gate 3 is confirmed the project’s execution. At Gate 3 will be evaluated, if the design and related engineering documents are ready for the prototype, and if the project can be executed according to the project plan with the selected concept. The environmental risk assessment question at the Gate 3 asks:

G3Q06: Does the product follow all relevant standards and regulations? Environmental and health & safety considerations still valid?

The Gate 4 is called “Readiness for Introduction”, and at this stage the product will be assessed by the steering committee, providing the project results are ready for the pilot and the production validation. Also, in the technology review, it is evaluated if the technology is mature enough for product development. For the environmental subject matters, check list at Gate 4 asks:

> G4Q24: Have risks for environment and health & safety been identified? Use the checklist on http://inside.abb.com/sustainability under ABB's Sustainability toolbox/Product development.

At the Gate 5, it is decided if all major technology or a business related risks are under control and if the product can be released for sales. This is the last gate where environmental aspects are asked on the gate checklist:

> G5Q50: Health & Safety and Environment: Have HSE related actions been managed to completion and the HSE checklist been updated?

In the main checklist, environmental questions are very generic. The HSE Checklist contains more specific questions, but since it is not directly a project document, it has remained unfilled in many cases. In this research, the aim is that the customer and authority requirements can be answered better. It requires a more precise approach in doing an environmental evaluation. An improved process as a result of a continuous improvement is targeted.

4 SUSTAINABILITY

4.1 Sustainability as a competitive advantage

Companies that are voluntarily increasing the level of their sustainability and environmental awareness may, for example, gain a competitive advantage in the future. There are also a vast amount of regulations, acts, and decrees, setting limits to emissions, waste management and reporting. These limits are set in order to keep the commitment to minimize global warming, limiting it less than 2 ºC degrees higher mean temperatures than the mean temperatures during pre-industrial times. The United Nations Summit for Climate Change in Paris in December 2015, probably sets new targets and new requirements. If burning coal continues, temperatures may rise even up to 4 ºC (New Scientist 2015, p. 10). This concern might change the requirements and the policies towards industries and companies that are not able to cut greenhouse gas emissions. They might get additional penalties, fees or taxes for not following the rules.

There are a lot of examples in literature about companies having successfully lead trough environmental programs, and gained benefits by means of increased efficiency and decreased waste. The profitability of a company can increase if materials are not misspent and the processes are tuned to save energy and raw materials. Even simple actions, such as changing conventional light bulbs to led-lights and printing double-sided papers has led to savings that matter, especially in cases where the company is big. For example, General Electric has reported saving $100 million in energy as a result of their greenhouse gas reduction program 2004 - 2008 (Esty 2011. p. 53). General Electric also set its Ecomagination targets to answer better to customer demand for less-emitting, energy saving products. It achieved good results by means of increasing their Ecomagination product sales and reducing the company’s absolute energy consumption by 13 per cent in 2004 - 2008 (Antila 2010, p. 52). In this success story, General Electric launched several Lean-based process improvement projects, Treasure Hunts, to increase the awareness of the environmental activities and the saving possibilities with the help of all their employees (Antila 2010, K. p. 53). Different types of motors and generators as well as solar panels are examples of less-emitting energy saving products.General Electric is also one of the leading suppliers of wind turbines.

For ABB, this General Electric’s success story could be an interesting benchmark target, since both are big companies and their product portfolios are partly identical. Having a green focus has been General Electric’s business strategy, which has been noticed widely in different industries. General Electric has also been quite often presented as an example, what comes of successful environmental solutions for businesses. After 2009, General Electric has continued setting new targets in lowering the amount of the absolute greenhouse gas emissions by 1 % (Malzman 2011. p. 206) as well as reducing their water usage. The focus in these improvement projects is strongly in engaging all stakeholders to achieving greener processes and products, as well as to reach the goal of sustainability by engaging three corner stones of the sustainability: people, planet and profits.

4.2 Can green products cost more?

A greener product can help a company according to the ISO-TR14062, to lower its costs, when the processes are optimized and the waste amounts reduced (ISO-TR14062, p.14). This can help a company to price the product lower, since the costs are also lower. But according to some viewpoints, at least some green products could even cost more or at least be more preferably chosen by customers. If a less-environmental product costs as much as greener product, the customer will in all likelihood, prefer the greener product. Especially public sectors with green procurement policies, such as the public building sector, might evaluate environmental aspects of the product higher on their decision-making criteria (Lavery/Pennell 2014, p.26). Higher priced environmental friendly products can be preferred even with a higher price if they can save the customers’ money over the whole products lifetime, for example, when consuming less fuel or electricity.

Also, a product built from materials that are easy to recycle, might increase the product's value. Recyclable materials in a product can also be a marketing value. In the future investors might also value greener products more.

4.3 Ways to increase sustainability

Business itself cannot be responsible, but people working for the business can (Burchell 2008, p. 85). Even though a company might have good processes and policies etc.in place, the company's social and environmental responsibility is a recognized value. People in a company can grow via a learning process to value new ways to work and think. However, it is a long learning process, and it does not happen overnight. A lot of training is needed, and explanations as well as examples need to be given. In a company developing processes, measurable targets, goals, and an environmental performance, follow-up is in a significant role.

As an example, people might find the electricity saving campaigns only harmful, if the office building lights are automatically switched off after the official office hours. Double sided printing might not be in all cases convenient. It may not be so easy to figure out how much it means annually, if everyone switches off their computers when leaving home. But when these issues are explained to the people, the greener mind-set will commence over the time. When the level of a greener mind-set among the majority of the employees is reached, the company starts to get the benefits of a sustainable society.

An authentically sustainable and an environmentally friendly enterprise support employees' eco-friendly choices also during their free time. Commuting to work is a big emitter of greenhouse gases in Finland, especially in the capital area. Approximately 20 % of the greenhouse gas emissions in Finland result from traffic, and road traffic represent 80 % of the total amount of greenhouse gas emissions coming from traffic (Oil.fi 2013). Supporting more public transportation and bicycling could show that a company is carrying a responsibility towards the society and the environment by reducing greenhouse gas emission from private cars. This also makes the neighbourhood safer, because of less traffic in the area. Also, noise from the traffic would be reduced. Noise levels are regulated especially in residential areas and they can be seen as a factor affecting the health and happiness of people. Preferential parking spaces for car-poolers, or for the people using electric or hybrid cars, could be provided by the company (Esty 2011, p. 134).

It is possible, that a company can also gain an additional benefit from supporting bicycling and public transportation in the form of employees eventually having less sick leaves. According to the World Health Organization, because of polluted air, an estimated 7 million people lose their lives every year (New Scientist b 2015, p. 12). According to a report by health researchers of the Lancet Association, published 23 June 2015, a society could benefit much by utilizing renewable energy instead of burning fossil fuels (New Scientist b 2015, p. 12). According to that report, doubling the share of renewable energy from the 2010 level of 18 per cent to 36 per cent could reduce healthcare costs globally by $230 billion annually by the year 2030, which means about 3 % reduction in annual healthcare costs (New Scientist b 2015, p. 12). Taking a climate change preventive, adaptation and mitigative actions also benefits the health of people. According to the Lancet report, there is a need for a framework for a strong, predictable carbon pricing system (Lancet 2015 p.2).

Promoting healthy lifestyles is benefitting the society and the planet, but also the company when green awareness increases and reduces the healthcare costs as a by-benefit. During the American Heart Association Meeting in Orlando in 8th November 2015, there was published a research paper by a Japanese researcher Hisako Tsuji, stating that people preferring public transportation are more healthy than the people driving private cars (American Heart Association, 2015). According to the study, users of public transportation were 44 percent less likely to suffer from obesity and 27 percent less likely to have high blood pressure. They were also 34 percent less likely to have diabetes (American Heart Association, 2015).The study took place in Japan in 2012 with 5908 people participating in the study.

A sustainability-driven enterprise gains business advantages, especially through a better company image and a brand value (UNEPb 2007 p. 11). Accessing certain markets might get easier, and being able to solve the customer environmental problems by providing suitable products, can help in increasing the market share and the revenues will grow. More efficient, less energy consuming and less wasting processes most probably will also affect positively on a company's net margins. Establishing a project around an eco-theme and finding saving possibilities might serve also the business side, and vice versa.

Embedding sustainability into daily operations and routines increases corporate green culture. It also helps an organization to be more resilient in invariably changing business environment and in volatile markets, where requirements tend to change relatively rapidly. An organization having a distinct green culture can act proactively and achieve the benefit being able to answer to new legislation or business requirements quicker than corporations having a reactive approach. Concern about sustainability and climate change, for example, are not matters for only corporate concern, but are the whole society's concern. An environmentally proactive company may not only benefit from better market positioning, but also gain a better public image (Esty 2011, p. 14).

In the book "Green to Gold" D.C. Esty presents the four steps for green evolution. The first stage refers to the business being eco-resistance. This means being aligned with the regulations and science. From eco-resistance, one step ahead is eco-compliance. An Eco-compliant organization is committed to meet the requirements of the laws. Eco-efficiency, as the third wave, is targeting to reduce the costs of waste material and excess energy consumption. The last step in the green evolution is eco-advantage, where, with an innovative approach, a company is able to provide to the markets products and services, which help customers to solve their environmental problems. (Esty 2011, p. 15).

The eco-advantage is exactly where ABB wants to be positioned. Providing systems, products and services, for example, for energy production and renewable energy, as well as innovative solutions for smart and distributed electricity networks, ABB is an operator in markets, which could set a precedent for new industrial norms in environmental performance.

4.4 Life Cycle Management

Life cycle management is not a single tool or process, but a cross-functional product management system, aiming through continuous improvement, to minimize products' and processes' social and environmental burden over their whole life time (UNEPb 2007, p. 18). Addressing socio-economic and environmental aspects cross-organizationally may be challenging. However, it is necessary to involve all functions working for the product, since all internal and external stakeholders influence improvements towards environmentally friendly and socially responsible products. The importance of all the functions attending to the life cycle management is described in figure 10.

Figure 10. Life cycle management organizational functions and responsibilities (UNEPb 2007, p. 25 –with permission of the publisher).

Life cycle management and life cycle thinking has many different interpretations and the most common interpretation is that life cycle management is considered to be a synonym to life cycle assessment (LCA). In reality, life cycle assessments are a part of life cycle management, tools that can bring relevant information on the product's life cycle (UNEPb 2007, p.22). It can that way work as guidance in the company wide life cycle management plan, where to put most effort, which operations and stages are most suitable for searching company advantage and innovations, and which steps are leading to the continuous improvement.

First step in an environmentally continuous design is life cycle thinking, which also requires strong management commitment. Typically in that kind of an organization, there exists a policy for environmental and sustainability objectives in general, and those are maintained by using the quality and environmental management system. The strong foundation of environmentalism and sustainability leads into the environmentally conscious design grounds. Different life cycle and analysis tools for the identification of all environmental aspects of the products can be used to plan activities that need to be taken in order to design an environmentally friendly product. Reviewing the processes and the products is needed for continuous improvement. The concept of the environmental continuous design process is presented is Figure 11.

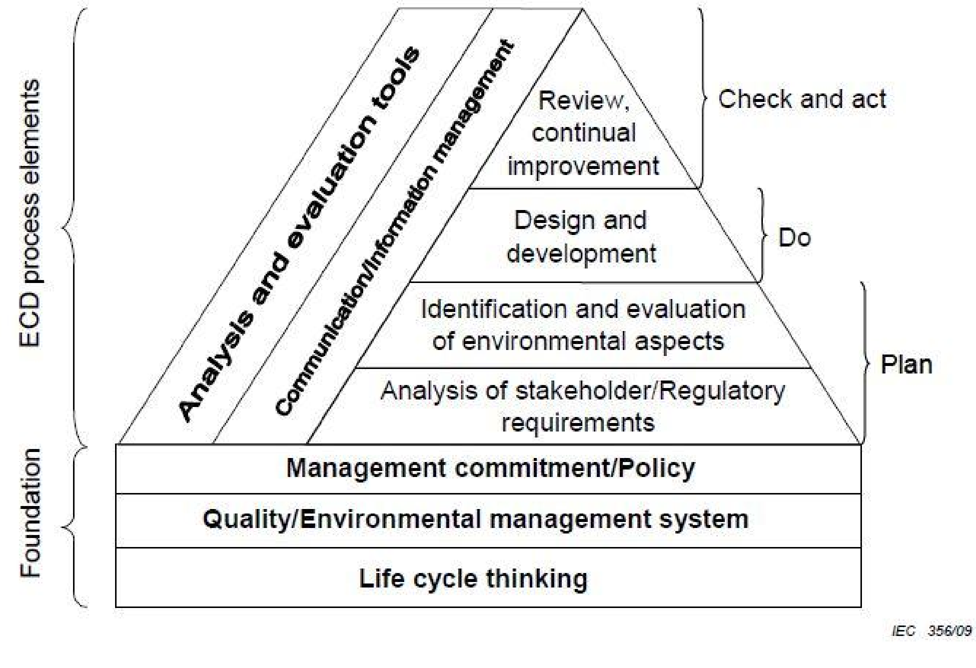

Figure 11. The environmentally conscious design process (IEC 62430 2009, Figure IEC 356/09 p. 15).

In the organizations, for designing products according to environmentally conscious design (ECD), it is required that the ECD process be implemented, documented and maintained as a constituent segment of the product's design (IEC 62430 2009, p. 11). A continuous improvement and involvement of the stakeholders shall also apply.

4.5 Life cycle thinking and tools

There is vast variety of different tools available for analysing life cycle impacts of a product and its production processes, and new ones are created all the time. Life cycle analysis is a method instead of merely being a tool. Different types of software are also available on the markets, and consultants are supporting companies in doing the analysis. Even though picking a most suitable tool for analysing a product's life cycle can be challenging, the advantageous part is, that there is all time more and more information ready and available, so analysing one's own products and processes in getting easier over time.

Simplified life cycle analysis are the most common because of their affordable pricing and comparatively quick analysing (Esty 2011, p. 103). Many companies utilize these type of analysing tools and continue developing their own tools suitable for their specific purposes. The main purpose of the use can be, for instance, for a designing engineer or a product engineer to do daily checks and decisions on products and processes, and possible trade-offs in materials, chemicals, filler materials or chosen methods, dependent on specific circumstances. In many cases, these tools give a score card and as result, they support decision making.

Extensive Life Cycle Analysis is typically demanding both from the money and time perspectives. However, these might be needed in order to be able to provide reliable data on the product's and processes environmental burden. This might be needed especially for environmentally friendly products, or products meant for environmental purposes.

4.5.1 Life Cycle Assessment (LCA)

The abbreviation LCA is sometimes interpreted as life cycle analysis, but the original meaning of LCA is life cycle assessment. In life cycle assessment, potential environmental impacts throughout the whole product's life cycle are assessed and reassembled into a portfolio based on all the existing inputs and outputs. The ISO standardization started developing the LCA standards in 1996, and specifically stated that LCA stands for "life cycle assessment" instead of "life cycle analysis", since an assessment contains qualitative information, while analysis is always a quantitative research (Maltzman 2011 p. 153).

When aiming for a life cycle assessment, it is important to define the targets. Depending on the target, the correct level and correct tools for doing the life cycle assessment can be chosen. A life cycle assessment can be seen as a four step framework as presented in Figure 12.

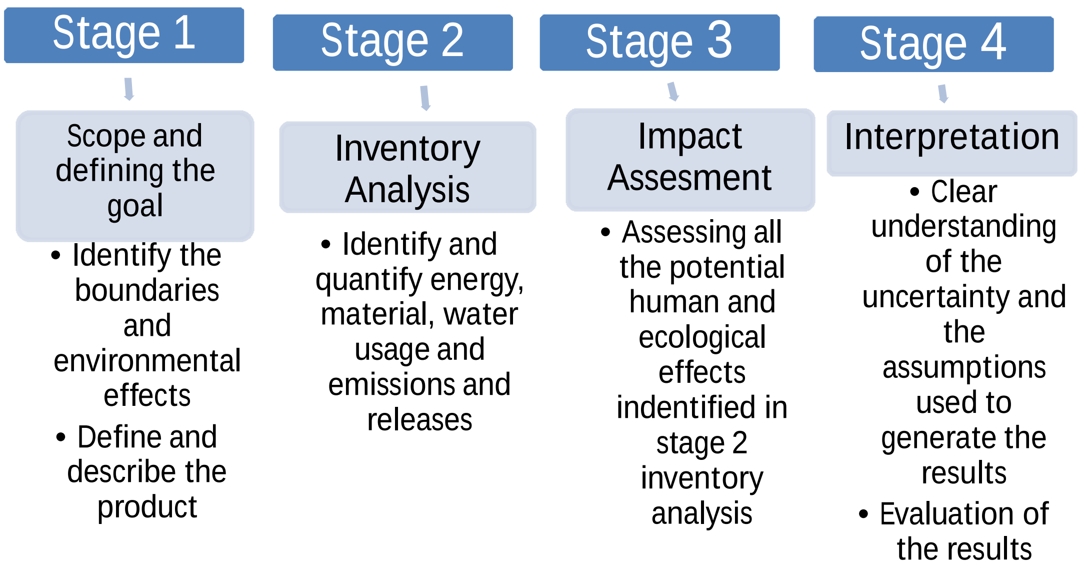

Figure 12. A life cycle assessment project according to ISO14040 (adapted from the text by Malzman 2011 p. 158).

A full lifecycle assessment might not be suitable for the purpose where a product's life cycle assessment is needed. Due to this, it is important to report the targets and the methods, as well as the tools used. If one does the life cycle assessment to the very same products, but by using a different tool, the results may vary, so this is the reason why an initiative target and methods should be reported alongside the primary results.

There are many simpler life cycle assessment tools in the market. At ABB, for example, a tool called the LCALight may be used for a quicker assessment of a product's materials, its energy use, transportations and recycling rates. However, the reporting possibilities with this tool's results are limited. For example, global warming potential, acidification potential, ground level ozone formation potential, nitrification potential and ozone depletion potential can be reported with the LCALight. For some purposes, this accuracy is enough, but for gaining a total understanding of the production process, the simplest tools are not suitable.

The threat of global climate change, general interests towards greener products, and the sustainability reporting requirements from customers and authorities, are driving towards more comprehensive reporting of a product's environmental impacts.

Industries are driven to be more resource-conscious not only for proving to be environmentally friendly, but for economical purposes. Life cycle assessment can also be a tool for understanding, if at some stage of the product's life cycle excess materials or resources are wasted. Understanding all the inputs and outputs throughout the lifecycle may help cutting some of the excess usage of materials or resources.

A compilation and an evaluation of the inputs, the outputs and the potential environmental impacts of a product help to understand the life cycle effects and the process itself, and it makes it possible to evaluate the process critically with respect to the improvements. Sometimes this method has been considered to take the product from the cradle to the grave. But rather it could be named as "cradle to cradle", since in the end of the product's lifecycle, there is no such place as a grave, because everything goes somewhere in the end.

4.5.2 Organizational LCA (O-LCA)

Typically, life cycle assessments focus on the products. Life cycle assessment for products can be very complex, and it would even make it more complicated to create methodologies in order to assess the social and economic performance. The maturity of economic and social life cycle assessments is not yet on the level of product assessment, and they are still lacking some methodology and guidance (UNEP ref c, 2015, p. 23). However, defining the analytical, managerial and social goals of the organization provides a solid foundation for future decision-making. An organizational life cycle assessment can work as a framework for tracking environmental performance in an organization over time and help in defining environmental improvement hotspots. It might also help in identifying hotspots inside the company's divisions, products, regions or factories. The O-LCA is not meant to be a tool for ranking and comparing different organizations, but instead for an improvement inside the organization (UNEP ref c, 2015, p. 34).

The benefit of an organizational life cycle assessment is that it helps in defining the performance, opportunities, and risks all the way throughout the value chain. This way the same burden exists, even though some production phase might be outsourced, or if some environmental problems are switched from one phase to another. The main goal of the organizational life cycle assessment should be to support sustainable development by reducing the environmental impacts of the organization (UNEP ref c, 2015, p. 33). Resource consumption reduction and other process improvements can also support the organization in its reduction of operational costs.

4.5.3 Life cycle assessments and environmental product declarations at ABB

At ABB, for some products, life cycle assessments have been made and environmental product declarations created on the basis of life cycle assessments. The life cycle assessment has been made with the chosen tool and with reliable partners for conducting the assessments. So far, environmental product declarations have been created for 86 products only (ABB 2015), and all these environmental product declarations can readily be found on the ABB Internet Page. Issuing more environmental product declarations in the future is probable because of ABB's extensive product portfolio and production amounts. ABB manufactures over 1 million products daily (ABB 2014). In Figure 13, an example of one environmental product declaration is shown.

Environmental Product Declaration

AC machine type AMB

ABB Automation

Environmental performance

The data and calculations are in accordance with the Product-Specific Requirements (PSR) for Rotating Electrical Machines dated April 2000, which specify the following baselines for the LCA calculation.

Functional unit
The functional unit for the LCA is 1 kW of rated output power.

System boundaries
The lifecycle assessment covers all environmental aspects for extraction and production of raw materials, manufacturing of main parts, assembly of the machine, transportation and use of the product, dismantling, fragmentation, disposal and recycling of scrap at the end of the product's life. It includes consumption of material and energy resources as well as emissions and waste generation.

Calculations are based upon an estimated lifetime of 25 years when operating 6500 hours per year. A European mix of energy has been used to calculate energy consumption during manufacturing and a European mix of energy to calculate energy consumption during, use and disposal.

The operational point chosen for the usage phase is 3600 kW, 1500 rpm and efficiency 97.8 %. The operational point in reality will vary considerably depending on the specific application.

Allocation unit
The factor for allocation of common environmental aspects during manufacturing (such as manufacturing waste) is calculated as the rated output power of the product in relation to the total annual production volume of the factory.

Resource utilisation	Manufacturing phase unit/kW	Usage phase unit/kW	Disposal phase unit/kW
Use of non-renewable resources			
Coal kg	11.34	635.27	-0.03
Copper (Cu) kg	0.24	0.00	-0.00
Iron (Fe) kg	2.58	0.00	-0.04
Manganese (Mn) kg	0.00	0.00	-0.00
Natural Gas kg	0.82	43.92	-0.00
Uranium (U) kg	0.00	0.02	-0.00
Oil kg	0.70	66.58	-0.00
Use of renewable resources			
Hydro Power MJ	0.02	0.00	0.00

2 ABB Automation

Figure 13. Environmental product declaration of an ABB machines product (ABB 2014).

Environmental information at ABB is divided into three main groups, and they are grouped according to the ISO14020. Environmental product information Type 1 is environmental labelling (ISO 14024). Environmental label, eco-labelling, is the most common approach in the consumer products and the consumer electronics. Examples of such environmental labels are European Ecolabel, German Blue Angel, Nordic Swan, and Nordic Ecolabel. Ecolabels are voluntary indicators of the product's environmental impacts.

According to the IS014024, environmental declaration can be also of a self-declaration type, which belongs to Type II labelling. These are statements or symbols used in advertising to promote environmentally friendly activities, for example declaring that a "product is manufactured fully from recycled materials".

Type III environmental product declarations, according to the ISO14025, are the most formal and informative indicators of the product's environmental performance. These types of declarations are based on the life cycle analysis and provide a way for a company to evaluate and monitor the environmental performance, and to also communicate it to external stakeholders. In the future, demand for environmental declarations might be increasing in industries alongside more generic sustainability reporting in companies' annual reports.

4.5.4 Designing life time of wind power generators

Wind power generators are designed at ABB to last for a lifetime of 20 years. This lifetime is expected typically also by the customer in the purchase specifications for the generators. ABB has delivered generators for wind turbines for over 30 years and some of the first delivered generators are still generating electricity. This means there are fully operating wind generators also well beyond the product's calculated life time of 20 years. Reaching the expected lifetime is secured through lifetime calculations of the system. Especially the insulation system is required to be designed for the entire demanded lifetime. Another design criterion is that services and spare parts need to be available minimum for the period of the required lifetime.

Generators also include wear-and-tear parts, like carbon brushes of the slip-ring unit or earthing brushes. The bearings have a limited operational lifetime as well. During operation, with proactive maintenance and monitoring, the targeted lifetime can be secured, and quite often even be exceeded.

4.5.5 Manual for operating, maintaining, and recycling of wind power generators

ABB's manual for operating and maintaining the wind power generator provides information on how to maintain the generator during its lifetime so that its expected lifetime may be reached. When the product is at the end of it its initial use, the manual also provides information for recycling of the materials. However, instructions given in the manual, for example, for recycling and disposal are only informative, since ABB provides generators for global markets, and local regulations may vary from country to country.

Wind power generators are typically packaged in wooden pallets, which can be burned, except some treated wood materials for overseas freight that need to be recycled according to instructions in the specific country. Plastic wrappings are recyclable and anti-corrosive tectyl paste can be removed from the surface with a cleaning cloth, and by disposing of the used cloths according to the local regulations.

Main steel parts, the frame, bearing housings, covers, and fans can be recycled according to local instructions. Before melting the steel parts, auxiliary equipment such as cables, bearings, heat elements, and sensors need to first be removed. The stator and the rotor are the main components, including electrical insulation materials, in addition to recyclable steel and copper. Stator copper can be separated in a heat treatment process, where the organic binder materials of the electrical insulation are gasified.

The heat treatment process is instructed to happen at a temperature of 380 – 420 º C, and the duration of the heat treatment should be a minimum of five hours after reaching 90 % of the target temperature. After-burning should happen in the temperature of 850 – 920 º C, and a binder few should stay in minimum three seconds in the burning chamber. The emissions of the burning process contain mostly O^{2}-, CO-, CO_2-, NOx-, CxHy-gases and microscopic particles. It is on the user's responsibility to make sure that the above process complies with the local legislation. Special care is needed in this process due to the amount of toxic gases, as well as high temperatures.

4.5.6 PDCA cycle (Plan Do Check Act)

The ISO Management Systems Standard for the Environment (ISO 14000) and for Quality (ISO 9000) suggest a systematic approach to life cycle management as well as for other activities. This step-by step approach is presented in Figure 14.

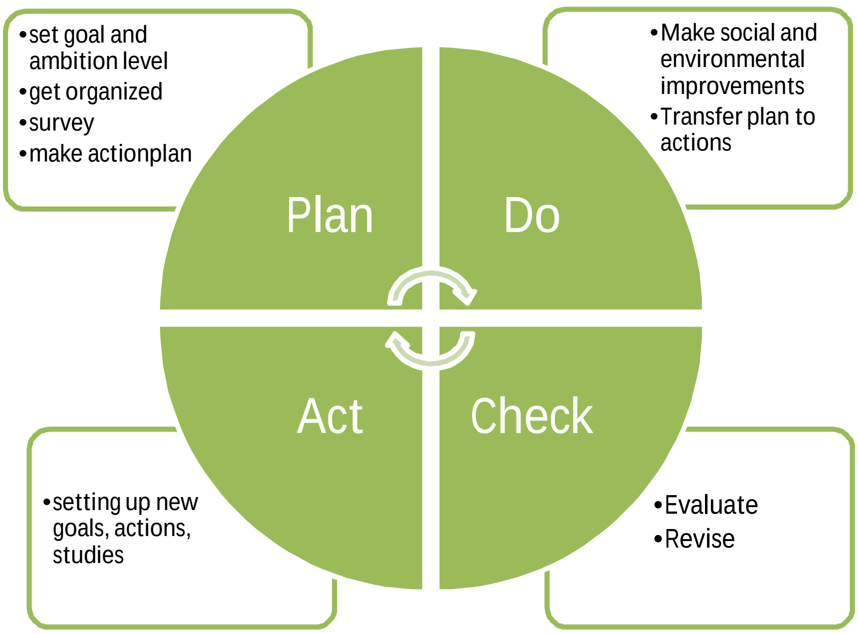

Figure 14. Plan-do-check-act – a step-by-step approach (ISO14000, UNEPb 2007, p. 38)

This approach ensures that the company is continuously improving its processes. It is not a certificate stating the company or the product in question is green, but that processes are monitored in order to ensure that viable improvements are lead though in the organization (Malzman 2011, p. 9). The Plan-do-check-act cycle helps also in identifying risks where environmental objectives might be in danger of not being reached, and corrective and preventive actions can be taken.

All of the steps are equally relevant, but the status survey is an essential starting point. The survey in the “Plan” Phase should include a survey of the markets and all internal and external stakeholders, including, but not limited to the employees of the company, the suppliers, the authorities and business associations (UNEPb 2007 p. 41). The performance should be evaluated also against the company’s targets, the company policy and other objectives. Figure 15 as presented also in the United Nations publication, shows the different aspects of a life cycle management initiative survey.

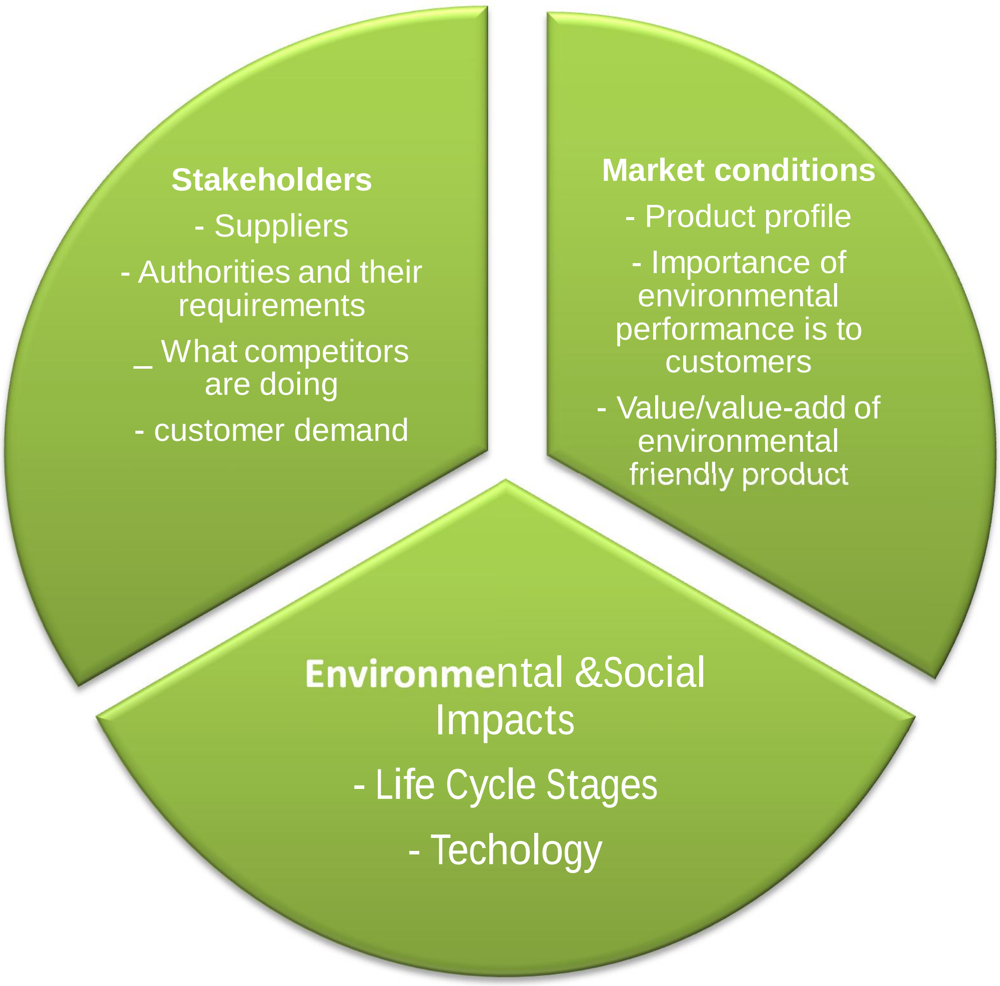

Figure 15. Life cycle management initiative survey, its stakeholders and aspects (UNEPb 2007, p. 41, with permission from the publisher).

4.5.7 Benchmarking

If good procedures are already adapted somewhere, the existing valuable knowledge could and should be utilized more by comparing, evaluating, sharing and adapting best practices to one's own businesses. The leading industries generally tend to be responsive to share information on best practices on a certain level. Many companies want to be the business leader, whose practices are recognized to be so advantageous, that they are benchmarked. Benchmarking is not copying but merely reproducing gained knowledge of the best and the most suitable practices, and modifying those to answer better to the own organization targets and requirements.

Benchmarking can be a respectable tool also in the environmental and sustainability objectives. Also in big companies benchmarking between different divisions and product groups could be used as an improvement and learning method.

5 ENVIRONMENTAL DESIGN REQUIREMENTS

From the 1990s eco-designs and green products has been presented to the markets. During this decade, the climate change concern has pushed this threat on the political and governmental agendas around the world. United Nations via its Environmental Programme, published in 1997 a booklet “Eco-design: A Promising Approach to Sustainable Production and Consumption” and when published, it was one of the first manuals in that field (UNEPa 2009 p. 15) Still, literature on this field is not numerous, even though a strong growth within past few years is visible.

The globalization and the economic growth and increased consumption on goods and electricity along the fast growing population of this planet has led to tighter regulations. Reporting responsibilities are also increasing. Recently, legislative requirements for restricting and prohibiting certain materials and chemicals have been imposed within the European Union and elsewhere (Soyka 2012, p. 85).

In the organization aiming for better environmental performance with an environmentally conscious designs and other methods, the key strategy is a communication. A communication, as easy it sounds, seem to be a real challenge in the organizations in general, and in many occupational satisfaction surveys, the lack of communication has been raised as a major improvement task. Notifying of the environmental aspects in a product design and development, provides to the employees information on the organization’s environmental policy and knowledge on product–specific environmental causes and effects. An environmentally aware organization should typically share the information on successful environmental projects or products inside the organization. It should be organized trainings on environmental issues, tools and legislation (ISO-TR14062 2002, p. 16). Internal communication should be seen as important as external communication. Successful internal communication on the environmental aspects may be a driver obtaining feedback from the employees on the environmental design and sustainability.

Greening the corporation may help in repositioning it better on the environmental scale internally, as well as externally, and it may benefit the company both in penetrating into the new markets and in keeping up with the competition. It can also gain an advantage in forms of reduction in the fees and the taxes in the future, if environmental considerations can be proven.

5.1 Authority requirements

There are increasing amounts of regulations, policies and guidelines, which companies need to take into account when manufacturing products and when aiming to design sustainable products. In this chapter, the most essential ones will be presented from an electrical machines designing point of view.

5.1.1 RoHS – Restriction of Hazardous Substances

Companies have been developing and deploying during the last decade ways, not only to comply with the ISO 14001 Environmental Management System, but also to comply with the mandatory requirements and the regulations set up in Europe and other geographies. In 2006, in the European Union area, there was established the Restriction of Hazardous Substances (RoHS), placing restrictions on the use of hazardous materials in electrical and electronic equipment (Soyka, 2012, p. 85).

The Renewed RoHS Directive (RoHS II) was published in 2011 and introduced to be effective from 2013 in all European Union countries. The renewed directive is applicable to all electric and electronic appliances, and new classifications were added to the renewed version for the clarification (Teknologiateollisuus, 2011). According to the RoHS II directive, compliance with the RoHS II directive is needed in order to use the CE-marking on a product.

The hazardous Substances defined in RoHS II are the same as in the original revision: Lead (0.1%), Mercury (0.1%), Cadmium (0.01%), Hexavalent chromium (0.1%), Polybrominated biphenyls (0.1%) and Polybrominated diphenyl ethers (PBDE) (0.1%).

5.1.2 REACH – Regulation, Evaluation and Authorization fo Chemicals

REACH (EC 1907/2006) is the European Union Regulation from 18th December 2006, concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) to protect human health and the environment (REACH, 2006). It is effective in all member states in European Union. The requirements for better identifying the chemicals used in products and production processes are setting the targets for the companies in monitoring, following up and reporting on the use of chemicals in products and processes. All supply chain operators need to have enough information on the processes in order to be able to monitor same things at the supplier locations. Certain chemicals are forbidden, and some might be used if the content percentage of the chemical is low enough, and the use of that chemical is authorized for the described purpose. Registrations are maintained in the centralized database of the European Chemicals Agency (ECHA) in Helsinki.

The ABB List of Prohibited and Restricted Substances is updated on the ABB Group level twice a year, in January and August, and it is mainly based on the updates of the EU REACH Candidate List published in December and June (ABB, 2015). The Candidate List of substances of very high concern (SVHC) contains, as per June 2015 update, a total of 163 different substances (EU, 2015). With the ABB List of Prohibited and Restricted Substances, containing substances relevant to ABB, the company is aiming to comply with the legislation to avoid harmful substances (ABB, 2015). By avoiding the use of harmful chemicals and materials, their risks to the environment and to the health of any stakeholders during the production and the whole lifecycle of the products can be avoided. A continuous follow-up is required, since according to the European Union SVHC (Substances Very High Concern) Roadmap to 2020 Implementation Plan, to the Candidate List might be presented thousands of new chemicals. From the Candidate List, chemicals might end up being forbidden. ABB in Finland uses approximately 2000 different chemicals, from which around 30 can be found in the Candidate List (ABB 2015). The company searches alternative options and sets deadlines, when some of the chemicals will not be used any longer.

RoHS and REACH and WEEE (Waste of Electrical and Electronic equipment) directive are examples on the mandatory requirements that the companies need to fulfil, in case they want to produce and sell their products to the markets. These directives are aiming for safer products and production methods in order to protect the people and the nature. The interest of the customers and the society towards greener products and overall sustainable performance proven by proper disposal and recycling, has led companies to report voluntarily on their environmental performance. The respect towards human rights and equality, as well as lowering emissions and preserving natural resources, is often mentioned in the company material. In this work, a proper environmental management system (EMS) and understanding of the product's whole life cycle with the help of life cycle assessment tools, are directing companies to provide information on their products and processes.

5.2 ISO 14001 Standard

The ISO 14001 is an international standard setting out guidelines for an environmental management system. It directs organizations to set goals for their environmental performance and improvement in their environmental objectives. Organization size does not limit the adequacy of the environmental management system. There are already over 300,000 ISO 14001:2004 certified organizations in 171 different countries around the world. (ISOa, 2015).

It is presumed in ISO14001 that an organization considers all its environmental aspects, such as the use of resources and efficiency, a climate change mitigation and adaption plan, a waste management, and pollutants, and also sets procedure for follow-up and continuous improvement. Adapting the ISO14001 standard into use in the organization, helps to comply with the statutory and regulatory requirements and improve the company reputation and image, as well as convince internal and external stakeholders (ISOc. p.2 2015). However, an organization can even choose not to accredit the standard by the third-party certification body, but instead to follow the guidelines of the standard in order to reach benefits in forms of better environmental performance, for example, through better used resources and lower amounts of waste and improved follow-up.

There has been recently released a new revision of the ISO14001 standard, called the ISO14001:2015 in September 2015. It has been established in order to meet better the latest trends, and to answer better to the increased need in the organisation, to observe the internal and external boundaries of environmental performance, as well as to have common terms with other management system standards, such as the ISO9001 (ISOb 2015, p.3). All ISO standards are reviewed and revised regularly in order to ensure their relevancy with the standards.

The main advancements in the ISO14001:2015 revision is the requirement for the strategic positioning of an environmental management system in the directive decisions and the strong leadership contribution. Requirements for the stakeholder-based communication strategy have been added, as well as higher emphasis on life-cycle thinking over the products life-time from the environmental perspective. Proactive moves to protect the environment should be considered as well. (ISOb 2015, p. 5,).

If an organization is certified according to ISO14001:2004, there is guaranteed a three-year transition period in order to apply for and meet the requirements of the new revision ISO14001:2015 (ISOb 2015 p. 5,). The ISO organization does not accredit the ISO14001 certification itself. The actual certification can be applied by inviting an independent certification body to audit the company practices against the requirements of the standard.

5.3 Other regulatory drivers for more sustainable products

There are many initiatives driving towards more sustainable products and processes. A responsibility in a business, and a desire to answer better to the customers’ requirements are the typical drivers towards sustainability, as well as the restrictions and obligations originated from the national and international regulations. In the European Union, there are several sustainability and energy-efficiency projects ongoing, where targets for improvements are set Union wide. Many targets are controlled by rules and acts. The economic growth of the European Union’s states needs to be secured without compromising sustainability.

The European Union is also driving for change and improvement through the Sustainable Development Strategy (EU SDS) which is regularly checked and revised, and it is meant to be a guidance on the national and international level (EU a, 2015). The key parameter indicators are set to follow that the improvements in energy efficiency of the electrical devices, buildings and mandatory energy efficiency certifications, are complied with. Large companies need to conduct an energy audit at a minimum every four years. There exist a large amount of regulations and policies, as well as acts and decrees in the area of sustainability. The European Union Directives can be found for an Eco-Design and Energy-related Product, Eco-Labelling, Eco-Management and Auditing (EMAS), as well as Environmental Technology Verification (ETV).

5.4 Electrical machines standards in wind power generators design

In addition to generic standards for Quality in ISO 9001, the Environmental ISO 14001, the Occupational Safety and Health OHSAS 18001, ABB follows a many other electrical machines standards, when designing wind power generators. Mechanical dimensions and tolerances are designed according to the ISO standards and electrical dimensioning and tolerances according to the IEC. The main standard for wind power generator design guidance is the IEC 60034 – the Standard for rotating electrical machines. It includes sections such as rating and performance, protection classes, cooling methods, mounting arrangement, electrical terminals, vibrations and insulation classes.

Other relevant standards from wind power generator point of view are, for example, the IEC 61400 - Standard for wind turbine generator systems, IEC 60204-1 Safety of machinery – Electrical equipment of machines (for general requirements), the ISO 281 for rolling bearings and the ISO 12944 for corrosion protection of steel structures by protective paint systems.

Wind turbine manufacturers require, that certain noise levels are not exceeded, not even in the components inside. Especially near, where people live, operational noise levels need be on a relatively low level for wind turbines. To test that noise levels are verified on a standardized method, the ISO standards, the ISO 1680 Acoustics -Test Code for the measurement of airborne noise emitted by rotating electrical machines and the ISO 3744 Acoustics - determination of sound power levels of noise sources, are followed.

Also, some EC Directives like the Low Voltage Directive's 2006/95/EC, the directive for CE-mark in rating plates, and the directive for EC Declaration of Conformity –document, are followed. Another directive followed is the 2004/108/EC- The Electromagnetic Compatibility Directive. Electrical machines are so called passive EM equipment and they are excluded from the scope of the EMC Directive. However, generators installed and connected according to ABB instructions fulfil the emission and immunity requirements of the directive.

5.5 Sustainable design tools

The majority of the tools and initiatives around sustainable and environmental design are focused on a life cycle assessment, which has been presented in the previous main chapter. Because of the complexity of analysing all perspectives of the products, there are many tools that help companies to provide sustainability information to their consumers, customers and other stakeholders. There are estimated to be at least 600 different tools available for such purposes (UNEP d, 2015. p. 5). The way of conducting sustainability analyses of the products is not mature, but it is very complex, which explains the large amount of tools available. All available tools do not necessarily support well enough all the problems confronted, and they might cause distrust (UNEP d, 2015. p. 5). Still, the need to define ways to measure sustainability of the products is getting more important. The exhausting of the world’s resources is getting even more severe and it is an obvious risk, when the population and economics are growing at the same time, as the consumption of goods and energy is increasing.

Product’s sustainability information should help in understanding the risks, the improvement opportunities and he measuring, as well as following up on the target. Managing the decisions and communication with stakeholders can be also managed with the help of some of the tools. These tools may help in providing information to the markets, for example, a declaration on a chosen topic, like greenhouse gases. Most of the sustainability attributes presented in the tools are environmental (82 %), while social attributes are in the minority (UNEP, d, 2015. p. 27).

Sustainability can be, according the United Nations Product Sustainability Information Tool Study, divided into categories based on the type of tool and its function (UNEP, d, 2015. p. 27). These different categories are shown in the Figure 16 below.

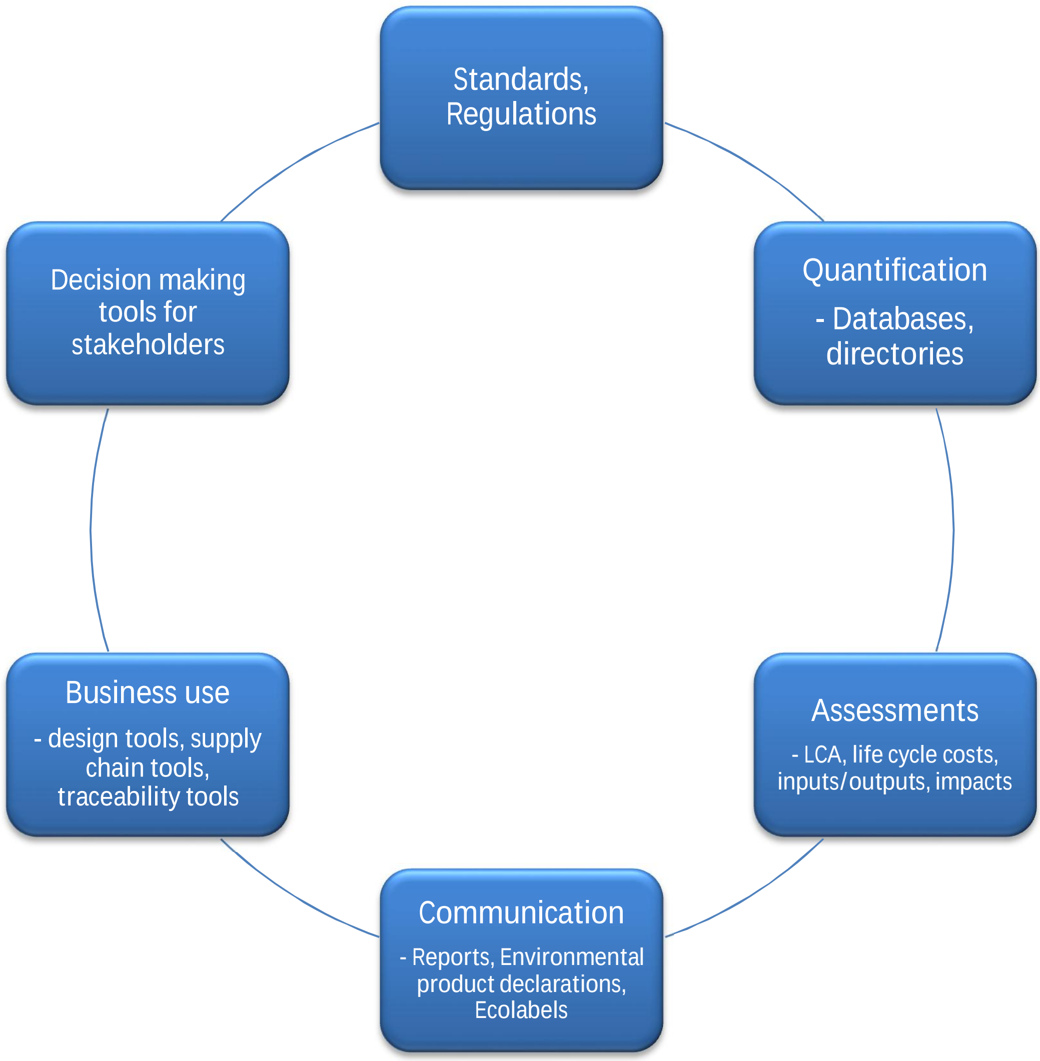

Figure 16. Sustainability tool categories (adapted from UNEP d. 2015 p.27).

The existing tools can support best in making life cycle assessments. Finding a proper tool to help to design sustainable products might be difficult. For example, for products like wind power generators, there are not yet suitable tools available in the market for designing a sustainable wind power generator. A generator engineering is a complex engineering project from electrical, mechanical and thermal dimensioning perspective. In these kinds of cases, a single tool itself cannot help to design a sustainable product, but a more sustainable design can be achieved by following company instructions in the design process of the product. These kind of company tools may be instructions or simple calculators created for certain purposes, for example for comparing alternatives such as transportation methods and packing options and material choices. Also, a checklist type of guidance could be regarded as a company engineering tool for sustainability.

Since the procurement is in an active role in helping to achieve a more sustainable design, sustainable processes need to be embedded also in the supply chain. Some tools such as Solidworks Sustainability and Autodesk Sustainable Design for Manufacturing are on the market as well as some other commercial solutions, but the problem with these are that they do not support fully the manufacturing process or all the functions, but are instead concentrating on certain areas such as in the environmental management of a factory (Autodesk, 2015). In the Solidworks Sustainability Program (Solidworks 2015), the tool seems to put emphasis on the redesigning and rethinking of things in an organization. This could be also more of a nature of a process or mind-set in an organization in a product development and an engineering phase.

The majority of the sustainability tools found in the markets, 82 % concentrate on environmental aspects, while only and 16 % of the tools evaluate both environmental and social attributes. Only 2 % of the tools are meant for social sustainability evaluation. (UNEPd. 2015. p. 29).

5.6 Greener engineering

The more interdisciplinary ideology and environment there exists in a company, the easier it is to start engineering from a green foundation. The economist of a company might not necessarily share the same views, and engineering, management and environmental specialists all view issues differently, and all from their own perspectives.

A good starting point for green engineering is a company, where the management has a strong knowledge and interaction of the subject. Actually, a green engineer originates from the company values, not from a single individual’s interest. However, a single individual’s opinion may matter. Green engineering starts from sustainable company practices: a company needs to have secured efficient recycling and waste sorting, have requirements for the supply chain and for continuous improvement processes and the quality, as well as have an environmental policy in place. Despite general belief, environmental engineering starts from the company values, and it is finally the designer who is responsible for designing the product for a sustainable future. The designer can choose materials from specified sources and from correct, energy saving methods. It is thought that it is worth investing on affecting attitudes of the designers in the first place, since sustainable engineering design (SED) needs to be applied from the very beginning of the product’s life cycle, and that is the responsibility of designing engineer (Johnson 2014, p. 72). A sustainable designing engineer is capable of balancing and optimizing the design and to take into account, not only the social and the commercial aspects, but also the environment and sustainability.

In a classic design-to- manufacture process, sustainability should be considered all the way when thinking of a sustainable life value model. Johnson is presenting in the book Sustainability in Engineering design that each phase in which a design could have an effect, should have a design related sustainable value as presented in Table 2.

TABLE 2. Sustainable life value SLV (adapted from Johnson, 2014, p. 99)

Sustainable Value	*Abbreviation*	*The measure*
Life Value	SLV	The measure of the environmental resource impact during the life of a product
Source Value	SSV	The embodied energy required in creating the raw material to manufacture

Design Value	SDeV	The energy used during design process
Manufacturing Value	SMV	The energy required to manufacture product
Use Value	SUV	The energy required during the life of the product
Disposal Value	SDV	The energy used in disposal of the product
Giveback Value	SGBV	How much resource is returned and can be reduced from the sustainable life value impact (SLV)
Maintenance Value	SMaV	The energy required to maintain the product

The designer should aim at having values in generic as low as possible in order to save the resources of the planet, but in sustainable giveback, values should be as high as possible, since it will balance the takeout of other energy and use of resources. The problem with the actual use of this type of model, although it is breaking down the product's whole lifetime into elements, is the task of actually getting the embodied energy measured (Johnson, 2014. p. 99). Some of the lifecycle evaluation tools might help but the analysing task will, in any case, be enormous.

The designer can influence many environmental design aspects such as to specify the raw materials and the structure and the manufacturing methods. The choices made during the design process affect also all the way through the product's life, since the designer can affect the maintenance characteristics and the disposal attributes as well. The sourcing team should do the decisions based on the design created, and support an environmental design with sustainable sourcing policy. Utilizing local suppliers could support eco-friendliness of the product through lower transportation emissions and costs.

5.7 4R approach

Because every product costs and manufacturing any product always consumes resources, the engineering challenge is to design a product so, that the manufacturing costs are as small as possible, but at the same time so, that there would not be a compromise between the cost and the environmental characteristics of the product.

A product's sustainability can be improved by using recycling materials. All around the world there have been efforts made to reduce the amount of landfill waste. This has to be considered already during the engineering phase of a new product. Eventually, product will be at the end of its life. This is why 4R's should be considered carefully during the engineering phase. It should be studied if the product and/or the materials in the product are Recyclable, Reusable or Repairable (Johnson 2014, p. 66). And the fourth R means Reducing. If the product can be designed originally so that it contains less materials and components, there will be less concerns in the end of the product lifetime. Another benefit from less components and less material is the weight of the product. The heavier the product, the more transportation, lifting, and maintenance costs over the time.

In the wind industry, typically the allowed component weights are determined. The assemblies, like a nacelle, are big and limiting size and weight help both in transportation arrangements and lifting, while building the wind park sites, and later on in the maintenance phase. The wind turbine manufacturers might limit the weight of key components, such as generators in their purchase specifications. Additionally, easy construction with fewer components is recommended for easier maintenance. Also, components should be designed so that the maintenance and the repair work is also possible up in the tower. Because of these limitations, engineering should already, in the designing phase consider, for example, the size and the weight of the components. The importance of designing proper tools for easy maintenance, like pulling out the bearing up in the nacelle, is essential to take into account.

6 THE RESEARCH OF THE ENVIRONMENTAL AWARENESS IN WIND POWER GENERATOR ENGINEERING AND R&D

This research was conducted at ABB wind power generator engineering and development and research for Generators during August and September 2015. In the initiative phase a work shop was organized, to discover the current level of knowledge and the starting point for the development task. The development task, as result of this research, is aiming for process improvement so that environmental awareness can reach higher level among the design engineering and the project management. Also in this study one of the main objectives was to create suitable materials to support design engineers, but at the same time support in documenting environmental performance during engineering and product development. Partly the study is also aiming to help wind power generators team to answer better to the increased customer interest towards environmentally friendly products and processes.

6.1 The research methods

This research is combining different methods. While this study is predominantly a case study at company ABB, the research itself is containing different methods in both data collecting and analysing. Since the researcher is insider in the company, the empirical data has been collected via long-term observing in the company. The challenge doing the case study as an insider from the research point of view, is staying neutral. At the same time being insider was providing an advantage in understanding the bigger framework, and the context, and it helped when acting as an independent facilitator in the workshops and interviews and questionnaires. The cross-functional understanding was needed. In many organizational studies in qualitative or quantitative research, gaining access to the participants might be difficult and might turn out to be the main concern (Symon 2012, p. 36). Also choosing correct participants for the studies should have a special focus. In this research gaining an access to the organization was easy and defining the participants was relatively simplified, since in the internal research all certain function employees were invited to the survey. Less participants were invited to the workshop due to spatial limitations. Since this research contained also questionnaires, the results of these questionnaires were sorted with quantitative research principles.

In the wider theoretical framework this research is linked to the sustainable business and to the environmental aspects in the business life. These aspects have achieved higher attention during recent years due to increased concern of a changing world: threat of the climate change and its impact, growing populations, changes in the economies, political relative strengths and an increasing consumption. The literature review around the theme has been performed prior to the actual case study, and the theory is reviewed in the previous chapter. In the public domain, specifically from the manufacturing industry point of view there has not been significant amount of earlier researches, so one of the targets was to understand better also the ways to influence the environmental objectives in manufacturing industry.

For the future improvements, the methods and the tools for analysing the product life cycle and the general methods for the design and the process improvements such as 4R concept (recyclable, reusable, repairable and reducing as presented in chapter 5.6.1) and plan-do-act-check cycle (presented in chapter 4.5.6) were assessed during the actual company research. The suitability of the design process concepts supporting in finding solutions to research questions was evaluated. The status of the missing environmental evaluation and documentation during product development phase, and reasons for that was aimed to be found during the company research. The literature review with the design concepts and tools was studied in order to understand, if some of the methods would support in improving the state of the environmental assessments of new wind power generator products. Since the environmental aspects are a big part of the sustainability framework, and generally more sustainably aware organization could support in having green company spirit, the mind-set part was kept in mind when doing the research.

The research plan was created so that answering to the research questions would be possible. It is required to identify the data and the evidence needed for answering research questions dependable, and keeping mind-set open for possible alternative views towards the research questions (Eriksson 2008, p. 26). Picking up the gauntlet of alternative views and not limiting the viewpoint to the pre-assumptions has been one of the researcher target.

In the beginning pre-fieldwork for the research topic was done by reviewing company processes and documentation and instructions related to the environmental aspects and sustainability. At ABB, the instructions and other materials related to the subject are collected in the intranet at site called “Sustainability toolbox”. One hypothesis in this research was, that even though upper level of the instruction and the guidance might be well in place, it might not support in practice in doing environmental choices in wind generator development and engineering and project management.

The design of the research was grounded on the theoretical and conceptual foundation of the literature review, company information, stakeholder relations, assumptions and hypothesis and the final research questions. Defining the actual research methods was based on the theoretical foundation to find a feasible way carrying out this research assignment. The study of the company processes was completed with the information how employees confront environmental design thinking. The online survey was the chosen method, supplemented with a workshop for collecting information of the environmental awareness inside the teams for getting comprehensive conception. Understanding the current state was presupposed to lead the way for defining new practices in order to increase environmental awareness, and support in creating comprehensive material for making environmentally conscious design choices easier, and to secure that appropriate documentation system is in place.

Customers' expectations were one of the interests of this research, since one hypothesis of this research was that since wind generators are going to energy production purposes, and especially for the renewable energy installations, this stakeholder group might be more conscious of requiring evidence of the environmental performance from their suppliers. To research the customer expectations an online survey was published to chosen customers.

6.1.1 Evaluating the state of environmental awareness at ABB in Wind generator engineering

The initial part of the research was performed at ABB global wind generator engineering and project management and product management functions mainly during August and September 2015. The starting point was defined with help of the empirical material research, continued by team work shops and questionnaires. The aim of this first part of the study was to observe, what kind of environmental information exist and is available for engineers, and what could be missing. Since continuous improvement is in the key focus, the aim of this research was also in the end to support the development of a greener engineering environment. The pre-assumption in this research was that most probably current way of securing environmental viewpoints during product development is lacking some documentation.

6.2 Online survey

Both internal and external surveys were completed with an online survey tool CAWP. The questions were created into the program, and link to the survey was sent via email. The CAWP tool allows sending responses to excel, which support further compilation of the statistics. The online inquiry was created by using a radio button type multiple answer choices.

Last field was left as an open text field for further feedback or commenting topics related to the inquiry.

6.2.1 Internal online survey

The internal research Questionnaire was open from 11th August to 21st August 2015. The Questionnaire was sent to 51 participants from the Product Group Generators engineering, product management, project management and development and research functions. The group of participants was defined by the work assignment in the organization. The research was a web-based survey with 17 multi-choice questions and one open question field.

The group of the people belonging to R&D, product or project management and engineering received an invitation to answer the survey questions by email. The reason for the survey was explained in the foreword of the survey. The inquiry was sent in total to 51 participants. In this survey 26 out of 51 answered in the term of the research leading to 51 % response percentage. This can be considered to be fair result in the voluntary inquiry for the organizational development purposes. The research questions and the summary of the responses are attached in the Appendix 1.

6.3 Summarizing of the internal survey results

With this survey a lot of valuable opinions and information on environmental awareness status were collected, also via open comment field. It was appealing to notice that respondents seemed to value the environmental issues. However, the trust towards ABB processes supporting environmental focus was valued lower than among the customers, and also awareness of ABB's sustainability targets was not on high level. From this research point of view, the most important notice was that existing environmental checklist is used very seldom and it is not saved with the project documentation. The further target in this research was to understand why checklist is not used and if it needs to be modified to fit better for generator development and engineering.

6.4 The usage of environmental checklist in generator R&D and engineering projects

The first question in the internal environmental awareness questionnaire was asking if the current environmental checklist is used in the project management and the engineering. Figure 17 is summarizing the responses of the respondents for whom this question is applicable.

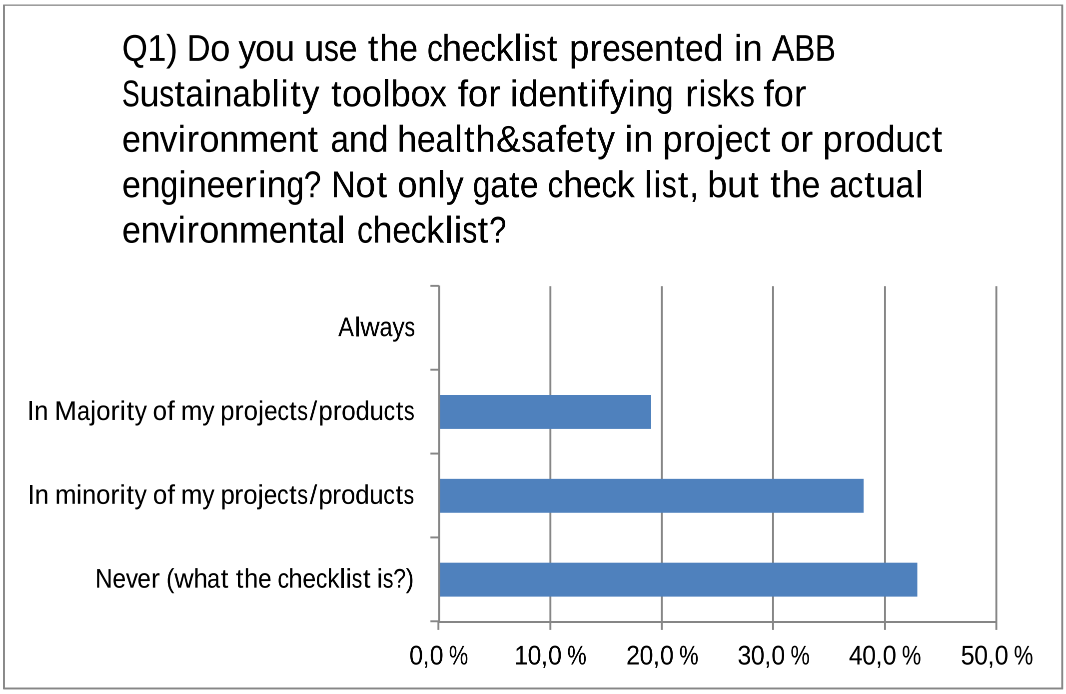

Figure 17. The use of Environmental and Healt&safety Checklist during the product and project management in generator product group.

For 21 out of 26 respondents the question was applicable, leading to the result that 42.9 % of these respondents never used the environmental and health&safety checklist in their projects, and 38.1 % used the checklist in minority of their projects. None of the respondents was using the checklist always, and in majority of the projects only one fifth of the respondents was using the checklist.

From the ones who used the checklist in their projects and products, documentation of the answers was lacking. 55.6 % of the respondents for whom this questions was applicable, were documenting the answers of the environmental checklist by saving the checklist. The checklist was saved always only by 5.6 % of the respondents and similarly 5.6 % of the respondents saved the answers in majority of the development projects. One third of the respondents was saving the checklist in some of their projects. The results to the question of saving the data are shown in Figure 18 below.

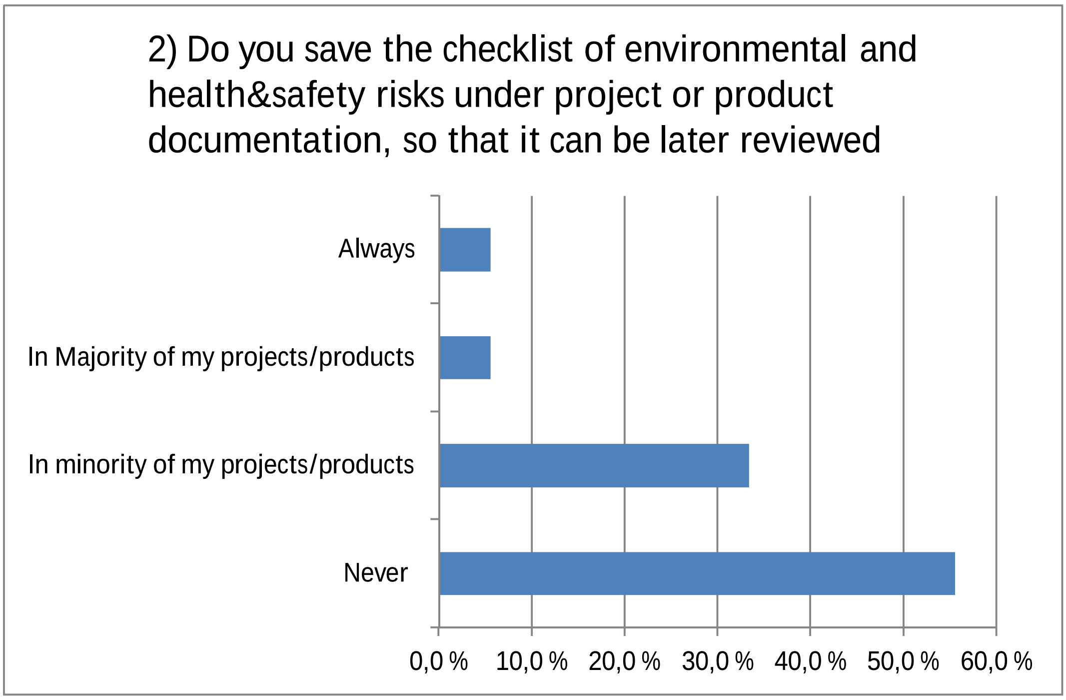

Figure 18. Saving the answers to the Environmental and Healt&safety Checklist during the product and project management in generator product group.

Unsaved data during the project may harm in the future, if there is a need to witness afterwards that environmental evaluation has been made during the project. Even during the same project this might complicate things, since the same checklist should be reviewed several times during the projects gate meetings.

6.5 Design related questions in internal survey

The engineering team felt quite intensively they do not have enough knowledge on the ways, how to affect on environmental performance of the product over the lifetime. 11.5 % of the respondents did not know the ways and 53.8 % replied they are mostly not aware of the ways how to influence the environmental performance of the product. Also the feeling of the possibilities to impress product's environmental performance in R&D, engineering, product management and project management functions was rather negative. In total 17 out of 26 respondents said they do not, or do mostly not have possibilities to influence product's environmental footprint as presented in figure 19.

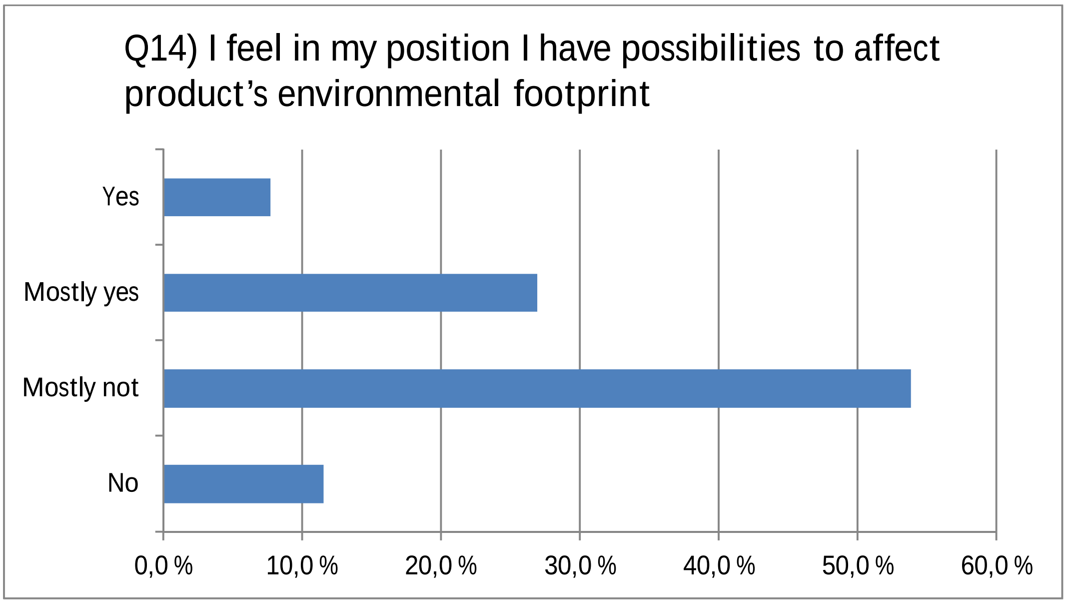

Figure 19. Most of the respondents (65, 4 %) in the questionnaire felt they cannot or mostly cannot have an effect on the environmental footprint of generators.

In the literary it is commonly stated that typically engineering and development and research are the phases where can be influenced most to the products environmental performance. Also the costs of the choices are typically the lower, the earlier decisions are made. Later, after the questionnaire, an environmental workshop for the team was held. In that session the reasons behind were discussed. One explanation for the feeling was that people do not necessarily recognize they are doing choices, at least from the environmental perspective, even though they are actually doing. Partly employees feel they really do not have ways to impress.

In the product design there are many areas which can influence the products environmental performance over the lifetime. At ABB in generators engineering, R&D and project and product management functions over one third (34.6 %) of the respondents believe electrical design would be affecting most to the environmental performance of wind power generators via lowering the operating costs over the lifetime as seen in Figure 20. In product, which will be used in power production over the decades, the purchase price is not the only measure to be stared at, but the cost of the ownership. The cost of the ownership includes not only the purchase price, but the cost of the operation over the whole life time, added with costs when the product is not functioning.

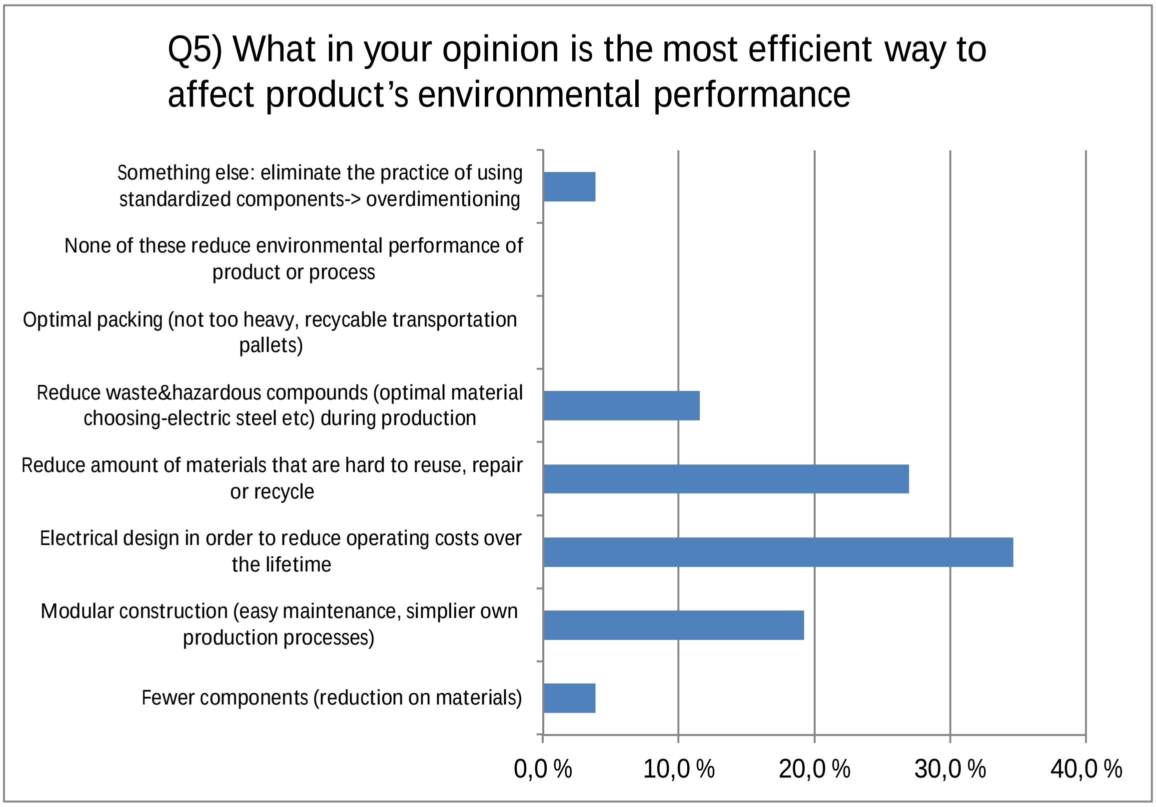

Figure 20. Best ways to influence wind power generators environmental performance according to engineering and R&D teams.

To the cost of the ownership can be influenced by designing a reliable design where the maintenance and out-of-order times are short, and the product is energy-efficient. A modular construction, supporting also the cost of the ownership, was seen as the best way to improve products environmental footprint by 19.2 % of the respondents. An easier installation could help also in own production, when less work hours and possible less machinery is needed for manufacturing the product.

Issues linked to choosing right material types and an optimal amount of materials, can support a wind power generator to be environmentally friendly according to 26.9 % of the respondents. 11.5 % of the respondents think that reducing waste and hazardous compounds during the production could support the eco-friendliness of the generator. Following the rules of the forbidden materials in the production processes should be a must. There might be still more to do on the area of reducing the waste amounts during the production. For example electrical steel is bought in certain widths to ABB. For some products this might be not purchased in optimal width, which leads to higher waste percentage than average. Since electrical steel can be recycled, it is not very severe, but in the long run handling of waste, including storing it in a production and transporting it, cause additional environmental impact. It can, in total, also cost more than settling to standardized, may be cheaper, widths of the steel.

In one open field comment it was notified that an over-dimensioning due to standardized designs can lead to the less environmental friendly design. There should be more options to choose from, since the product range and customer specifications vary so much. That was an interesting viewpoint. Generally it is believed that standard components are saving money, when less storage titles is needed and components can be ordered in bigger batches. But even though it might save money, it does not necessarily in the end be an environmental solution, if it leads to choosing too big or too much energy consuming components. Later it would be interesting to lead trough in the organization another study to gain an understanding, in how many cases it is really chosen over-dimensioned component or material due to a standardization. Alternatively it could be studied, if in the calculations too big security puffers lead to over-dimensioning that could have an environmental and cost impact. Over dimensioning can lower the environmental friendliness of the product, when too much raw materials is used, or the cost of using and maintaining the machine is higher, or more electricity is consumed over the life time. In a generator design over dimensioning could mean for example jumping to a bigger frame size machine, and having more copper and steel in the active material design.

6.6 Awareness of the company sustainability targets

The sustainability targets of the company were not very well recognized among the respondents of the survey as shown in figure 21. From 26 respondents, 20 stated they are not at all, or mostly not aware of the company's sustainability targets. This is quite understandable since upper level strategies and visions are not communicated frequently in the organization, but should be studied on one's own initiative in the intranet.

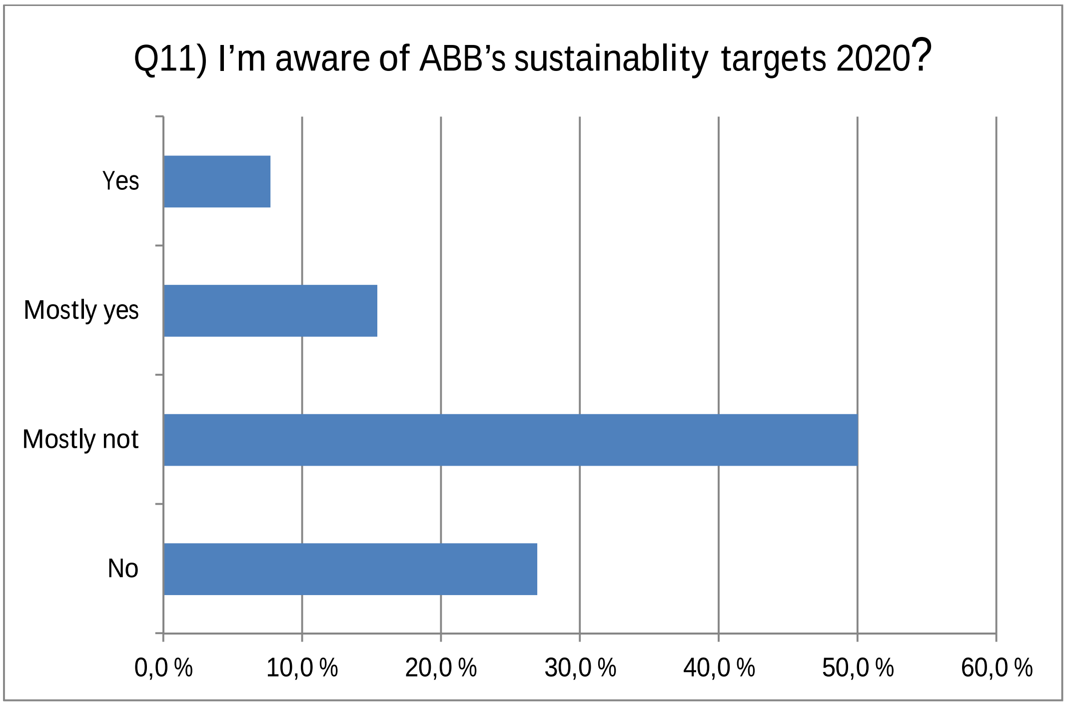

Figure 21. In total 76.9 % of the respondents were not or were mostly not aware of the company's sustainability targets.

6.6.1 Remote work and travelling opinions in the survey

The remote work was part of this research since it is often mentioned as a way to reduce environmental impacts of an office work. The question 17 in the survey was asking what could be the best way to lower the company's environmental impact in the office work. The share of the answers is shown in figure 22.

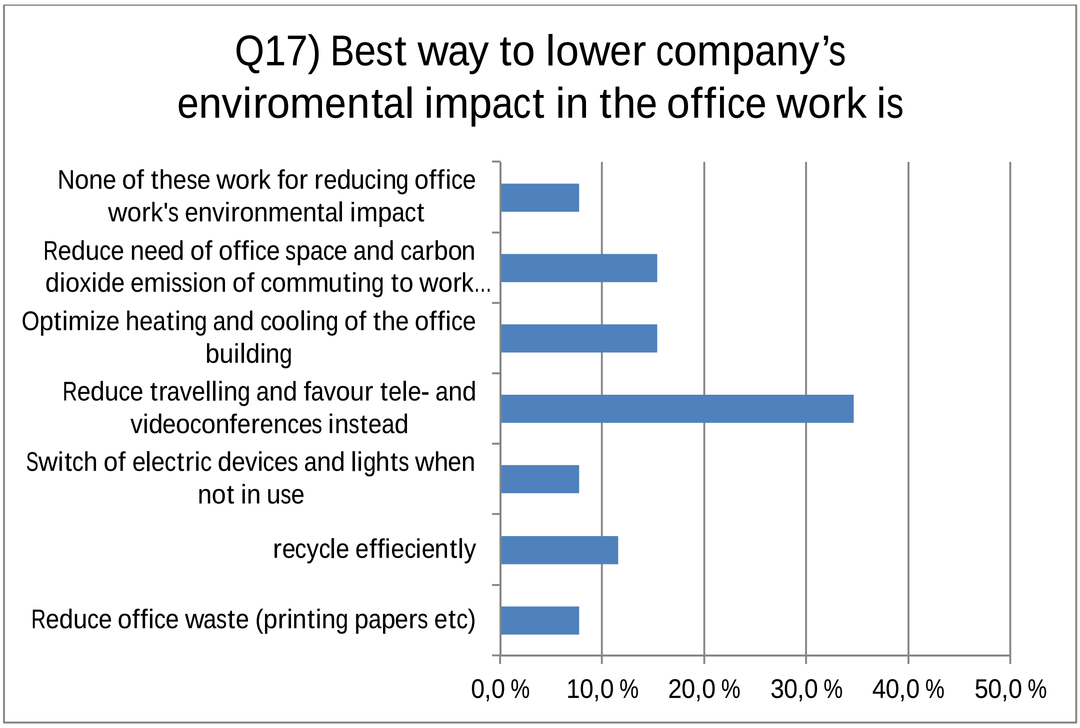

Figure 22. Research question 17: What would be the best way to lower environmental impact of office work at ABB?

According to this study 15.4 % of the respondents stated that offering better remote work possibilities would serve as the best way to lower the environmental impacts of the office work. The majority of the respondents, 34.6 %, were supporting an option to reduce travelling and favour the video- and teleconferences instead. At ABB some new video-meeting rooms has been equipped lately. As an improvement, for phone meetings, proper loudspeakers installed in all meeting rooms could support in having efficient phone meetings. The problem with mobile phone loudspeakers is relatively poor sound quality, especially if both parties of the meeting have several participants in a big meeting room.

In the literature it is commonly stated that supporting public transportation and bicycling and offering flexible working solutions could both increase the employee satisfaction and reduce the environmental impact. The less firm office space is needed, the lower are also the operational costs of the space, including but not limited to cleaning, heating and cooling and air conditioning. It was mentioned in the comment field, that ABB should support more flexible working from home. This could be an issue impressing the positive company image. It was also suggested that ABB could attend the national remote work day, which in 2015 was held in 8th October. ABB has not so far attended that event.

ABB campus in Helsinki is located just next to two railway stations, and it was proposed that ABB should support or even push employees to utilize more public transportation options. Since new ring railway connection was opened in July 2015, the connections to ABB Pitäjänmäki campus from different parts of the capital area are even better. However, from global perspective ABB factories and offices do not always locate in so easy to reach locations.

All of the responses are not reviewed in this summary text of the questionnaire. The questionnaire questions and replies can be seen in in Appendix 1.

6.7 Focus group work shop

To glean further information on environmental objectives in the Product Group Generators, a workshop on the environmental awareness and the development ideas was held in 22nd September 2015. The researcher of this study acted as a facilitator of the workshop. The participants were invited from R&D, engineering and project and product management and additionally from environmental management functions at ABB.

It is important in a company research, that attendees get the feedback of the results. It is also essential to explain the background and the aims of the research for the target group in advance. Sending invitations well in advance prior to the event need to be secured. Invitations were sent to 27 people, but the target was to get 10+ participants attending. Invitations were sent for more persons than expected to be participating, since it is typical that people might be occupied for customer project meetings, travelling, or otherwise be prevented from participating. The workshop participant target was reached since 16 persons representing all the target functions were attending.

The main purpose of the workshop was to review the feedback from the questionnaire performed earlier, and to have an opportunity in dialogue debate of the results and development ideas and concerns. During the workshop it was admirable that attendees were so active and participatory. It helped in composing the view on the developments areas and needs.

The preconception was that current HSE (heath, safety and environment) checklist is not fully suitable for Generators, and it is used very seldom in the project.

The relevant notice during the workshop was that even though the project management would initiate the environmental evaluation during the product development, maintaining the information during the product's lifetime is in the key role. Older structures should be maintained so that the compliance with the requirements is not limited to the development phase. Typically old designs do not need automatically upgrading to meet the all the time changing requirements. However, if design is reviewed for other modifications, the compliance with current requirements could be reviewed. For example the listing of the hazardous materials and districted and prohibited substances in updated frequently. At ABB the ABB list of Prohibited and Restricted Substances is updated twice per year.

It was re-confirmed in the workshop, that the current checklist is not in active use. Because of the missing documentation on the environmental performance, as an outcome of the workshop, the need of creating a HSE Checklist better suitable for product group Generators purposes was registered. This revised checklist should not be a separate checklist as today, but a fixed attachment in the project gate checklist. It should guide better in reviewing Generator development projects from the safety and environmental perspectives, and also include the dimension of the main responsible roles and the project phases. Since a supply chain has a lot of power to dominance product's environmental performance, this way responsibilities for the environmental evaluation during the project could be targeted for all applicable stakeholder groups.

It was also suggested, that in case there will be a very specific checklist, a template of such could be saved. A template in this context does not only mean a model filled checklist from previous project, but a template of a typical product evaluation, which could be updated with the product specific information. The risk in any type of template is that template is used as it is, and not updated to be product specific.

Sometimes it has happened, that the checklist, which is a separate attachment elsewhere, has been answered, but answers have been documented in the different place. This has led sometimes to a situation, that when master document (in this case HSE checklist) has become obsolete and been deleted, and answers for the questions have been saved without the actual questions. And then they cannot be even checked afterwards, since master document for questions is no longer available. Especially if the answer has not been a free text explanation, but only answer "yes" or "no" it does not give any kind of usable information of the evaluation afterwards. That is why it is very important in the future to attach checklist and answers both with project documentation.

6.7.1 The role of the supply chain

The role of the supply chain was emphasized many times during the workshop. The supply chain management should be responsible when choosing the reliable, environmental suppliers. ABB has internal purchasing standards for the raw materials and the components. This means that supply chain can do selections, but inside the limitations of the internal standards. Also a general auditing and the supplier code of conduct rules apply. ABB also has a supplier sustainability developing process, including supplier trainings, assessments, auditing and monitoring the performance. Towards the suppliers there are the minimum requirements and expectations, and the suppliers should comply with the ABB code on conduct.

6.7.2 Life cycle Assessments for wind power generators

The need for a LCA in the future is presumable. Even though a LCA is very extensive and typically require remarkable amount of work hours, and in many cases require an external partner with expertise in conducting a life cycle assessment, leading to high cost of the assessment, it could be seen worth doing. The asset of knowing deeply the whole life cycle of the product is the easiness of putting efforts on right aspects, and the ability of answering to all the time tighter requirements.

6.7.3 Rare earth materials in wind power generators

Most of the generators are containing materials that are easy to recycle, like copper and steel. But generator can include also rare earth materials. According to the wind power consultant's (Consultmake 2014) technology report, it is forecasted that technologies like direct drive gearless technology could penetrate stronger to the markets by 2020 especially in the offshore to achieve reduced OPEX costs (Consultmake, 2014, p.6). Direct drive gearless solutions require a generator with high amount of magnetic materials. Securing the availability of the rare earth materials is one of the aspects that should be reviewed in the material and the environmental assessments. In the workshop it was discussed of a leasing option. To secure return of rare earth materials back to ABB a leasing option could be one solution. Some industries are already utilizing leasing to secure that materials are recycled back.

For creating the new environmental checklist the workshops gave essential information, what kind of objectives should be reviewed very closely, especially from the generator manufacturing point of view. New checklist should guide to monitor relevant objectives. Other ideas like additional trainings on environmental aspects and increased know-how and cross-organization participation, can also be set as a target based on the workshop.

6.8 The external research

The external customer research was conducted during August and September 2015 between 15 – 28.8.2015. This part of the study was done by choosing five wind turbine manufacturers, and empirically study their materials and thoughts about environmental objectives, mainly via company websites and available annual reports or separate sustainability or environmental reports, if that kind of material was available. Earlier environmental inquiries and questions from the customers were also noted as a background material of the customer requirements.

Second part of this research was qualitative research via customer online survey. Respondents were chosen from ABB wind generator customers. Respondents were handled anonymous, and response could not be combined with the company and customer answering. Since customer companies are confidential information and names are irrelevant information from this study perspective, only the answers and customer expectations and their impression on the environmental performance of ABB were studied. The purpose of this part of the research was to get an understanding how ABB’s wind generator customer field feel the environmental performance and the requirements and secondly, if they can foresee something to be changing in the requirements in the future.

Inquiries were sent moderately to five different customer companies and to ten different respondents. Only three questionnaires were returned during the survey period, which leads to response percentage of 30 %. Response frequency was expected to be low when doing this kind of survey in the customer field. Also, since link to the online questionnaire was sent to email addresses, it was notified, that many were out of the office. When being travelling or on a vacation, questionnaires are not the first thing to consider. A link to the survey was sent to a very limited group of recipients, and a reminder of the survey was sent two days before closing the poll to gather remaining answers. Taking these obstacles into consideration, it was appreciated to receive at least a few viewpoints and opinions to be analysed, and represent in this survey the voice of the customer.

6.8.1 External customer survey results

According to the survey results, an environmental performance is a valuable supplier performance indicator. All the respondents answered “yes” to that question. Similarly congruent opinion was towards the question if proven environmental design could be a competitive advantage. All three customer respondents said that proven environmental design could be a competitive advantage. Also two out of three respondents stated that proven environmental design could be valued in the product price more than less environmentally friendly, answering “yes” to that question. Even according to third respondent environmental design could possibly be higher cost as shown the result for question 11 in figure 23.

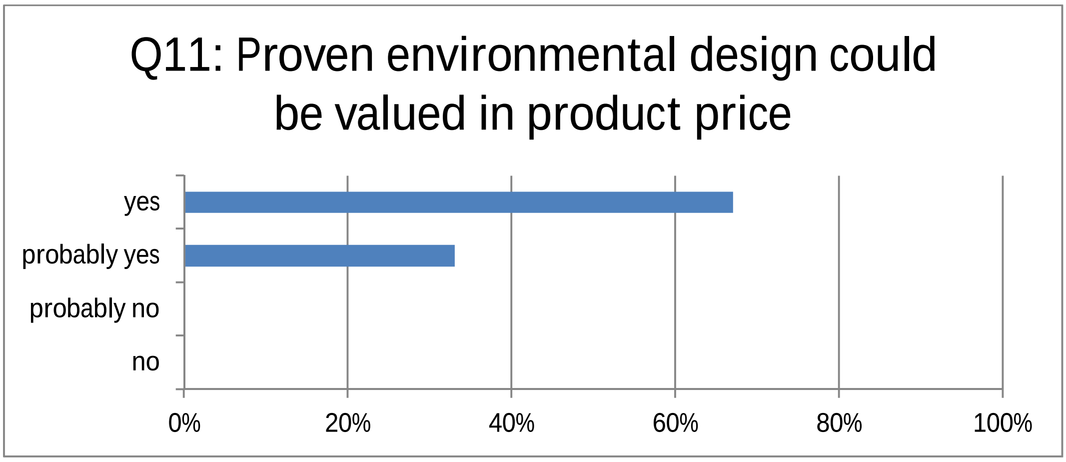

Figure 23. Results in the question if environmental design could be priced higher than less environmental.

When said “proven” environmental design, it gives an impression that a company providing a product or services should be able to show an evidence and a track-record throughout the process, to verify that product is designed and manufactured according to the environmental friendly practices.

It cannot be testified that environmental friendly sustainable product could in real life cost more even though in this research the attitude towards higher pricing of the proven environmental design was promoted. However, having environmental design might give a business advantage, especially when the regulations get tighter.

7 CONCLUSIONS

7.1 Research conclusions and suggestions

One general and suggestive remark of this research has been that follow-up actions of already implemented processes and ways to operate are an essential part of successful operations. If things are not done according to a plan or they are useless for the purpose, even the best practices and instructions can be compared to empty frames missing the picture. This research also taught that even though a process or an instruction in itself might be of good quality, it might require some updating before it can be fitted for a specific purpose. For this reason, it is advantageous to review processes, instructions and established ways of operating regularly. This is important even in circumstances where things do not change, but since the production environment and requirements tend to change over time, continuous follow-up and improvement actions are required. For the follow-up, the process introduced in ISO-standards, is called the “Plan-Do-Act-Check” as presented also in the chapter 4.5.6 in this research.

The following chapters present ideas on how to increase the environmental awareness inside the organization to be able to match with future requirements rising from the legislation and customer requirements.

7.1.1 Internal reasearch conclusion

Based on this study, it is suggested that targeted training should be arranged to the needs of research and development, product engineering, and project management teams. This training should always include a very specific example of how in each project phase, resources or energy could be saved as well as how an environmental perspective could be studied and documented especially for this product group. Although general impressions towards the legislation and the requirements of the authority was that information could be found and be readily available, however, the amount of material has been such, that sometimes it has not been so easy to find which requirements are relevant, which are not for product the product group in question.

The sustainability targets for ABB for the year 2020 were not very familiar to the employees answering the questionnaire, since 76.9 % were not aware of the targets at all. Also, 38.5 % of the responders in this survey were of the opinion that ABB processes do not have an environmental focus. A generic communication of the sustainability and the environmental objectives could increase the general awareness of the company's environmental targets inside the organization. That could lead to an organization where sustainability is actually a proactive value.

According to published studies, presented also in this research in the theory part, favouring public transportation and bicycling and walking instead of commuting to work by a private car, can have significant effects on the human health, therefore it is suggested that ABB could launch a campaign where healthy choices are promoted. There could be even some sort of a reward system at least during a health promotion campaign if not permanently.

7.1.2 Customer research conclusion

Since the amount of participants in the customer survey was very limited, too far-reaching conclusions cannot be drawn from that. However, the survey gives some impression on how ABB's customers of wind power generators are currently feel about the environmental design and the environmental requirements also in the future. Since ABB was valued as a sustainable company, it has reached the target of having generic processes in place and well organized. The impression of a company having sustainability targets has been marketed throughout the company very effectively.

Because all the participants in the survey believed that environmental requirements from the authorities as well as from their customers would most probably increase in the future, this should be taken into account. More detailed information of the design process and manufacturing is worth collecting and documenting, so that the environmental performance can be witnessed. Having a well-functioning process in place also on a practical level is important. Suitable material also for customer specific purposes, with relatively small efforts, can be collected.

7.1.3 Further studies and actions suggested based on the research

It was a clear signal from the customers that during audits, environmental questions will be presented, and observations made with regard to the environmental performance of the company. To support this, a more efficiently structured environmental checklist specifically designed for wind power generator purposes would support both engineering teams in their task to develop products as environmentally friendly as possible. It would also help the project management and sales and the quality team to answer the customer questions during a product or a process audit. If the checklist is generic enough it could be utilized also in the whole product group, meaning using it also for other motors and generators.

During a renewable energy exhibition or in a similar event where ABB is present, customer survey could be renewed. There the questionnaire could be saved in tablets used already in many ABB exhibitions to collect a customer data and inquiries. That way more responses could be received to get a more comprehensive view of the customer opinions and expectations. A major emphasis in this assignment was to study internal processes for continuous improvement, so the exiguity of the customer opinions was not a real an obstacle in this research.

The awareness of the policies around the environmental aspects should be on a high level in the organization. Otherwise it is not possible to be pro-active, and it leads to missing the opportunity to be superior in sustainability and positioning better on eco-advantage field (presented in chapter 4.3.). If adapting new procedures happens only when forced to do so by the authorities or the customers, the company is positioned after many other more active companies. ABB is already well on the track in following actively the requirements and policies, but since the global market area is bringing extra dimension to the follow-up, procedure to follow the product and the market area specific information and changes could be studied deeper. Best ways to share relevant information inside the organisation should be discovered based on an additional research.

For further studies, it might also be interesting to benchmark some other big companies working in the manufacturing industry. The benchmarking company need not necessarily be working inside the same industry field with ABB but should be in any case a bigger company with engineering, production and global operations. Since the emphasis would not be in upper level instructions and processes but on how the environmental objectives are secured in practical level, this task might be a bit challenging. It could be useful to study the status in other ABB product groups as well, if similar problems have been notified.

7.1.4 Improving availability of product related information

So far no environmental product declarations have been created for wind power generators. At ABB a procedure on how to assess environmental impact of similar size of motors already exists, so this target should be reasonably reachable. It has been documented already since 2008 that the existence of environmental product declarations has been requested by some of the wind power generators customers. The way of doing the environmental impact assessment could be utilizing reasonable accuracy and using a simplified LCA and reliable partner in assessments.

It is suggested that suitable simplified model for wind power generators life cycle assessment is created. It will be an advantage to show environmental performance on easy-readable format providing an environmental product declaration to stakeholders. The environmental product declaration could be done per generator type and size, not per each generator. That means that the environmental product declarations could be created in the first place for some of the platform products, like the most common output size of doubly-fed generators, the induction generators and the high speed permanent magnet generators, where product variation is not that big, and material amounts and processes are resembled inside the same product frame size category. Variation in the processes and materials is higher in the medium and the low speed permanent magnet generators, since there products are semi- or fully integrated to be part of the customer's drivetrain. This also affects the generator design remarkably and in these products diversity might be too widespread in order to be able to issue an environmental product declaration and LCA applicable for these products.

7.1.5 Instructions and tools for engineering and project management

Based on the research, the stakeholder opinions and the workshop notices, it was decided that new checklist need to be created, and it need to be a firm part of the project's gate model checklist. The actual integration of the Health and Environmental checklist to the gate checklist needs to be confirmed by the template owner of the official project gate checklist. The new checklist should instruct better to answer environmental questions from the generators' perspective, observing the most critical points. For the continuous improvement also, the use of a new environmental checklist should be followed regularly: for each project in project meetings. It should be followed, if the new checklist could be further improved after the test use period. Essential dimension of the new checklist should be the responsibility matrix, so that all the functions involved in a specific area of concern should review and give their comments.

A new part of the check list compared to the old one would be to define all the parties that should give comments to each environmental or safety related question. This way the impression that all environmental checks and decisions are made by the project management only could be avoided. The responsibilities matrix helps in understanding the complex interfaces, and might help in further follow-up of the environmental aspects. Currently the same environmental questions are repeated in different gates according to the existing procedure. In the new procedure, environmental and health and safety questions could be a decision gate specific unless for some specific reason same question should be highlighted again. In the beginning of the project, questions can be more related to generic ways to operate, and when in later phases the production of a prototype has started, more design related questions might be more relevant. At least reviewing same the questions five times is not necessarily the most optimal process.

During the literature review it was noticed that some commercial designing tools exist to support design processes of products to become more sustainable. Electrical machines, like generators, require special dimensioning and analysing tools, and having separately a tool for analysing sustainability did not look supporting the business. Current commercial sustainable design tools might support better in simpler consumer product designing. However, the specific sustainability tools can be covered with precise enough environmental checklist and the instructions related to it. The new environmental checklist is improved by adding responsible organization functions, where main responsible function/s for certain question or checkpoint are market with x, and supportive functions with (x). The functions that are involved with the environmental checks during the product development project are presented in Figure 24. The checklist presented here is an example and does not give a comprehensive view of the planned new checklist. The new checklist will not be presented in this research since it will an internal document for ABB.

ID	Product Mgmt	Marketing & Sales	R&D (Technology)	Manufacturing	Supply Chain Mgmt	Service & Support	Project Mgmt	Others	Others	Others	Question	Details	
G1OHSQ1	x	x	x	x	x	x	x				**Does the project team work environmentally concious way generally?**	Examples: Project team uses tele- or videoconferences, when suitable, with internal and external stakeholders, to reduce environmental impacts and emissions from travelling. The proto type will be manufactured at nearest factory project team (and customer location), if possible. The parties avoid unnecessary printing ect. Descripe the actions.	This supports ABB sustainability objective "Products and Services for a Better World"
G1OHSQ2	x	x	x	x	x	x	x				**Does the project team work at "safety first" principle?**	Examples: Team members report always a hazards or near miss events officially with ABB tool for such events. Travelling safety alerts from travel agency are taken into account . Team members have informed emergency contact persons to ABB data base. Team members have attended to obligatory safety trainings at ABB. When visiting stakeholder (suppliers, customers etc) related local safety instructions are followed in addition to ABB policy. Stakeholders visiting ABB are given safety information and gear if visiting factory.	This supports ABB sustainability objective "Safe and secure operations"

Figure 23. New Environmental checklist with responsible functions - example of the generic questions.

Also sales have a role in the evaluation process of environmental aspects. In sales role customers can be contacted to clarify and agree on certain points that may have an influence on environmental performance: transportation related aspects, suitable batch sizes, required storing time and protection, parts that can be returned, such as lifting lugs, shaft protections and in some cases transportation pallets, or special lifting tools or support beams. Also some performance parameter requirements of the product can have an environmental impact.

From the theory part of this research at least principle of for 4R's (recycle, reduce, repair, reuse presented in Chapter 5.7 in this research) for designing the products could be refreshed as a main ideology for improving the environmental performance of the product. Also for the process itself Plan-Do-Act-Check cycle should be used in order to secure that, in the future, the new checklist will be used in the projects, and also to gather information how it could be improved. Other improvements, like decision on a process, how customer environmental questions are answered, and how internal documents created during the project, should follow later. Also, then the actual environmental checklist should be revised again after gaining a proper process understanding after a life cycle assessment.

7.1.6 Stakeholder communication

The representation for an external survey was limited but if reading the results in a simplified manner, it looked as if the customers would be more aware of ABB's sustainability targets than the company's employees. This could be interpreted so that the customer communication on the sustainability objectives has been more successful than internally. Or the company respondents were too conservative in evaluating the level of their knowledge on the targets. Since a successful internal communication can help in creating an organization, where environmental and sustainable targets and tools are clear for the employees, an effective way of communicating the sustainability targets also internally should be created. In many companies more attention is put on external communication and communication materials.

At ABB there has been a high focus level on occupational safety during work hours and also outside the workplace. Integrity and equity and discrimination policies have also been trained deeply throughout the global ABB organization, which cover already part of the company sustainability pillars. The environmental aspect could be communicated similarly throughout the world at all ABB facilities. Some of this internal communication could increase the consciousness on environmental aspects more generically, and partly focusing on the office work environmental viewpoints, and production related aspects based on the target group in question. Since ABB is a global company and the national targets and requirements on environmental objectives may vary from Asia to Europe and US, some of the more targeted and local training courses and communication packages should be planned locally.

7.1.7 Process improvement

One main observation during this research was that the environmental checklist is basically not used for wind generator R&D and engineering as mentioned earlier. The process in place, but it does not seem to work optimally in practice. A systematic monitoring and improvement of processes is suggested in the ISO standards.

The plan-Do-Check-Act process model can be used to manage the process also in the environmental management. This research served as a check point for inspecting the existing process. There is a comprehensive gate model used in the projects and the environmental aspects are included already in gate model. Additionally, the environmental information is collected in the intranet under a “Sustainability toolbox”.

During this research, it was noticed that some of the generic material could be revised to be more targeted for a particular focus product group. At ABB there is a wide-ranging variety of products. Even inside the divisions, there is an extensive variety of products. This means that effective environmental checklists could be adjusted on the Product group level, to have similar type of products and similar type of check points most relevant during the development and the engineering phase of a new product.

7.1.8 Manual updating and other instructions for customers

Currently, the manual gives good instructions for operating and maintaining the machines, for storing the generators and also instructions for the disposal phase. However, the manual could be more specific regarding the recycling instruction. Since it is very generic, and also meant for the end user’s use, it does not give detailed information of the procedure to return, for example, supplier parts. Reusable supplier parts could be, for example reusable transportation pallet, lifting lugs and shaft locking supports. Instructions for collecting and returning reusable supplier parts should be given anyway, if not in the manual, then in some other format or in an attachment with each delivery.

7.1.9 Trainings

It is commonly thought that especially environmental consciousness is a value and a way of thinking, and it is not something that can be established overnight. The company can increase the awareness by trainings and committing people for taking the environment into account. The management should show a commitment and an interest towards environmental topics to create an environmentally friendly company culture. When a company supports environmental choices at an everyday level, environmental aspects can be raised up better also in product development.

In the environmental awareness survey in generator R&D and engineering and product management, 92.3 % respondents thought ABB should provide more targeted environmental materials and trainings for engineering, R&D and project management. On Product Group level there should be an environmental specialist or similar expert capable to sort out the information available on environmental aspects, and relevant for each function and product category.

7.2 Sustainable future

In a sustainable future, the lifecycle of the product will be well-known in detail. A life cycle assessment is used for designing low environmental impact products to support a company’s sustainable growth. According to ABB Sustainability report 2014, 51 % of the revenue comes from energy efficiency related products. The growth in revenues can be reached because of increased energy demand and disposing the challenges of more complex electricity network, where remote, off-grid communities powered by renewables come more regular. Also challenges of the energy storing and the control of diverse distribution networks with many nodes, supporting technologies suitable for rural areas and emerging markets are on the roadmap of sustainable growth. Establishing sustainability and environmental targets with follow able key parameters and continuous follow and develop processes also in sustainability, ABB can meet the vision “power and productivity to a better world”.

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Environmental workshop with ABB Product Group Generators R&D, Engineering, and Project Management. 22.09.2015.

APPENDICES

APPENDIX 1. INTERNAL ENVIRONMENTAL AWARENESS QUESTIONNAIRE

ABB

Environmental awareness questionnaire

Place: ABB Oy, Helsinki

Time: Questionnaire 11. – 21.08.2015

Participants: Project managers and engineering of PG Generators

How organized: Used ABB Lotus Notes based Web-inquiry tool CAWP

Q1: Do you use the checklist presented in ABB Sustainability toolbox for identifying risks for environment and health&safety in project or product engineering?

- Identify risks for environment and health & safety. Use the checklist on http://inside.abb.com/sustainability under ABB's Sustainability toolbox/Product development.
- AI:
    - Never (what the checklist is?)
    - In minority of my projects/products
    - In Majority of my projects/products
    - Always
    - Not applicable in my work

Q2: Do you save the checklist of environmental and healt&safety risks under project or product documentation, so that in can be later reviewed?

- A2:
    - Never
    - In minority of my projects/products
    - In majority of my projects/products
    - Always

- not applicable in my work

Q3: Do, you, in your opinion, know enough on ways to affect environmental performance of the product?

- A3:
    - No
    - Mostly not
    - Mostly yes
    - Yes

Q4: Do you feel you have enough information on authority requirements and legislation regarding this product group (such as requirements from ISO 14001, REACH directives (districted or prohibited chemicals etc.)?

- A4:
    - No
    - Mostly not
    - Mostly yes
    - Yes

Q5: What in your opinion is the most efficient way to affect product's environmental performance (if none of these, you can fill in your suggestion in the end of this questionnaire in free form field)

- A5:
    - Less components (reduction on materials)
    - Modular construction (easy maintenance, simpler own production processes)
    - Electrical design in order to reduce operating costs over the lifetime
    - Reduce amount of materials that are hard to reuse, repair or recycle
    - Reduce waste& hazardous compounds (optimal material choosing-electric steel etc.) during production
    - Optimal packing (not too heavy, recyclable transportation pallets)
    - None of these reduce environmental performance of product or process
    - Something else

Q6: Customer values environmental performance

- A6:
    - No

- Mostly not
- Mostly yes
- Yes

Q7: Proven environmental design can be competitive advantage

- A7:
  - No
  - Probably not
  - Probably yes
  - Yes

Q8: Environmental requirements from customers will be increasing in the future

- A8:
  - No
  - Probably not
  - Probably yes
  - Yes

Q9: Environmental requirements from authorities will be increasing in the future

- A9:
  - No
  - Probably not
  - Probably yes
  - Yes

Q10: ABB should provide more targeted environmental materials and trainings for engineering, R&D and project management

- A10:
  - No
  - Probably not
  - Probably yes
  - Yes

Q11: I'm aware of ABB's sustainability targets 2020

- A11:
  - No
  - Mostly not
  - Mostly yes
  - Yes

Q12: ABB's sustainable sourcing enables low environmental impact products

- A12:
  - No
  - Probably not
  - Probably yes
  - Yes
  - I don't know

Q13: Which is the phase in which you think can be affected most in product's total environmental footprint

- A13:
  - Mechanical engineering
  - Electrical engineering
  - Production process
  - Supply chain
  - transportation and packing
  - I do not have an opinion
  - None of these

Q14: I feel in my position I have possibilities to affect product's environmental footprint (material choices, modularity, process choices)

- A14:
  - No
  - Mostly not
  - Mostly yes
  - Yes

Q15: ABB is a company having environmental focus

- A15:
  - No
  - Mostly not
  - Mostly yes
  - Yes

Q16: ABB's processes support environmental focus

- A16:
  - No
  - Mostly not
  - Mostly yes
  - Yes

Q17: Best way to lower company's environmental impact in office work is

- A17:
  - Reduce office waste (printing papers etc.)
  - recycle efficiently
  - Switch of electric devices and lights when not in use
  - Reduce travelling and favour tele- and videoconferences instead
  - Optimize heating and cooling of the office building
  - Reduce need of office space and carbon dioxide emission of commuting to work by supporting remote work
  - None of these work for reducing office work's environmental impact

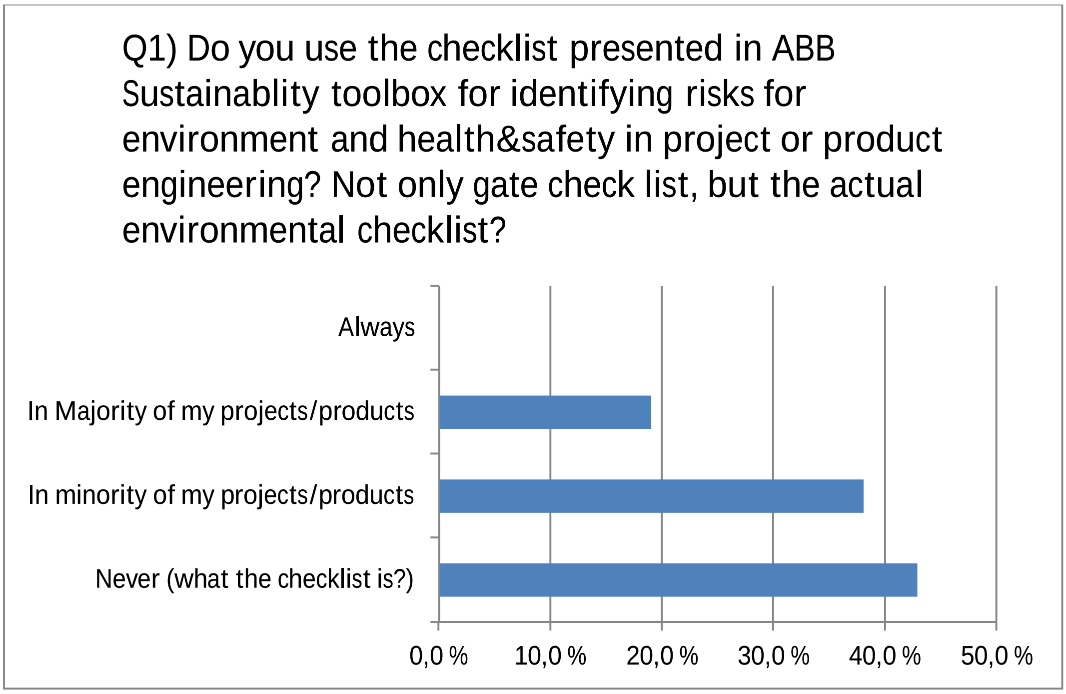
Q18: Open field for any further comments or answers

APPENDIX 2. ENVIRONMENTAL AWARENESS QUESTIONNAIRE RESULTS

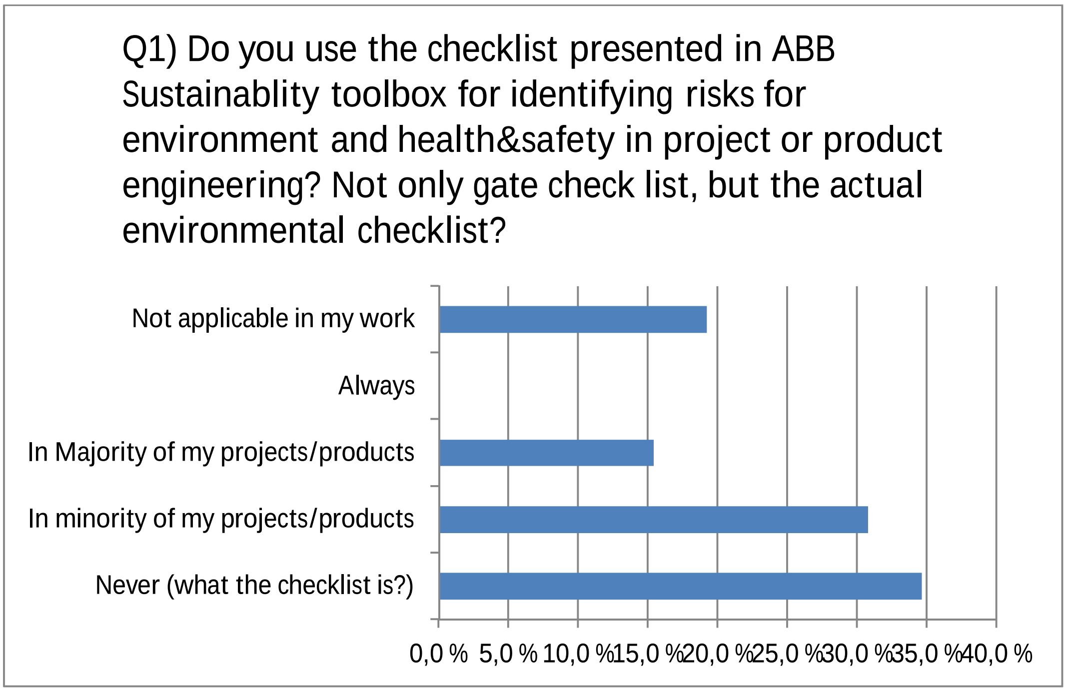
Internal Environmental awareness questionnaire results

Time	*Survey recipi-ents*	*Respondents*	*Response per-centage*
11 – 21.08.2015	51	26	51%

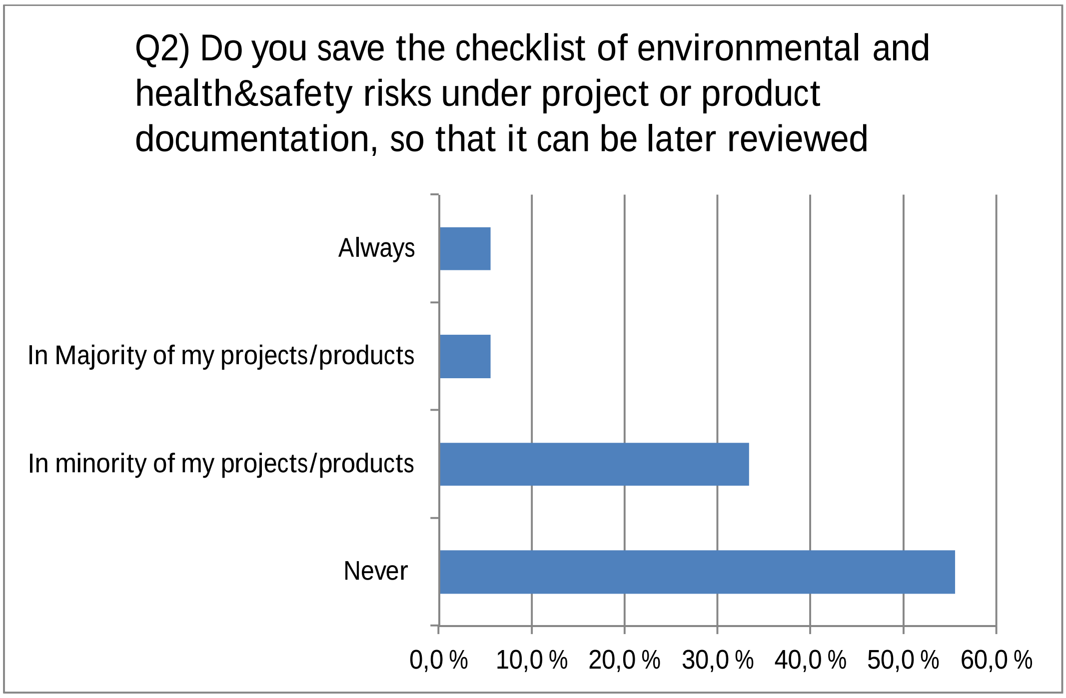
Results collected from the survey data. In some questions was possible to answer “not applicable in my work”. In these cases, answer will be shown both including and excluding that answer.

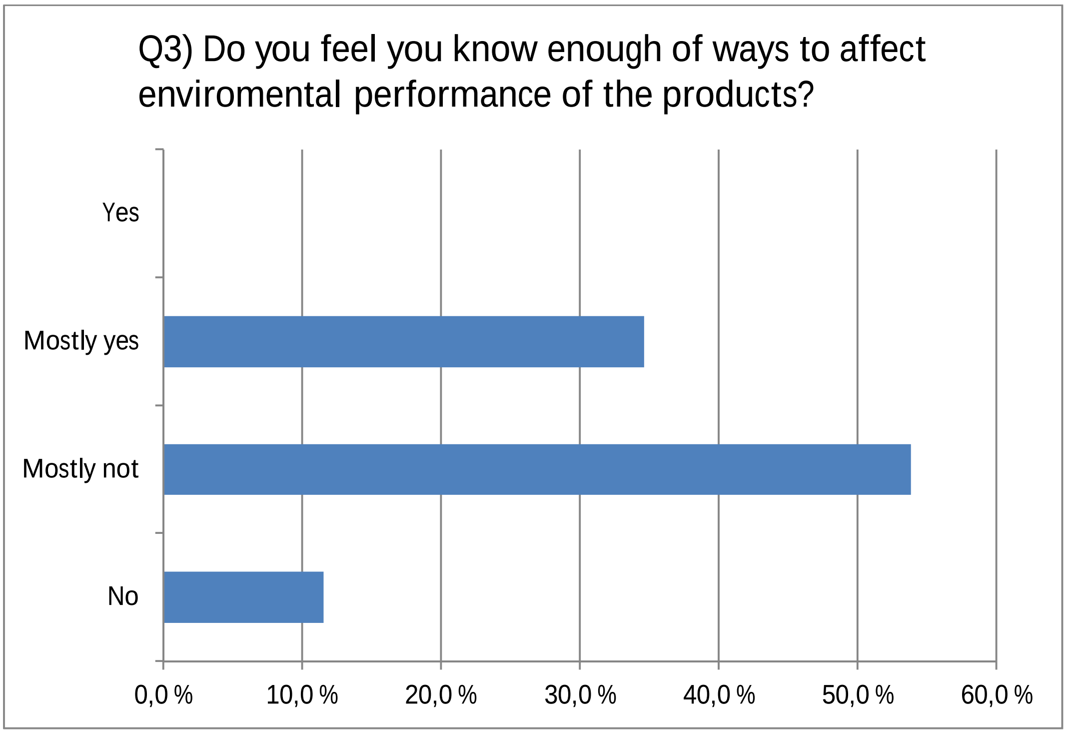


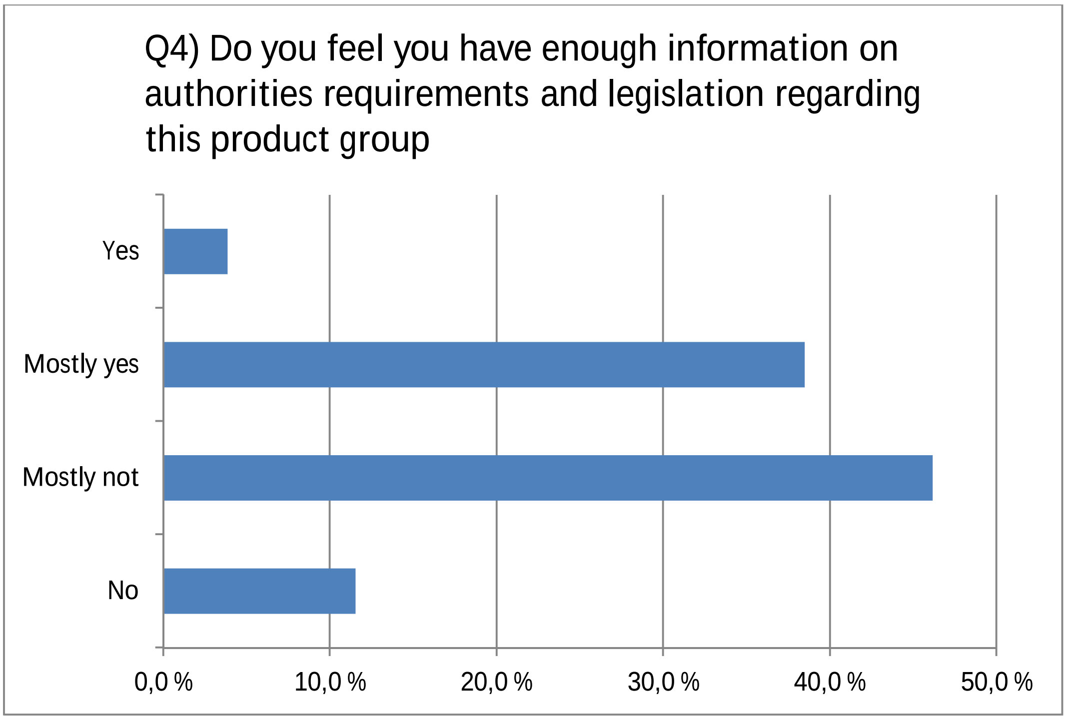
Answers from the respondents for whom this question was applicable.

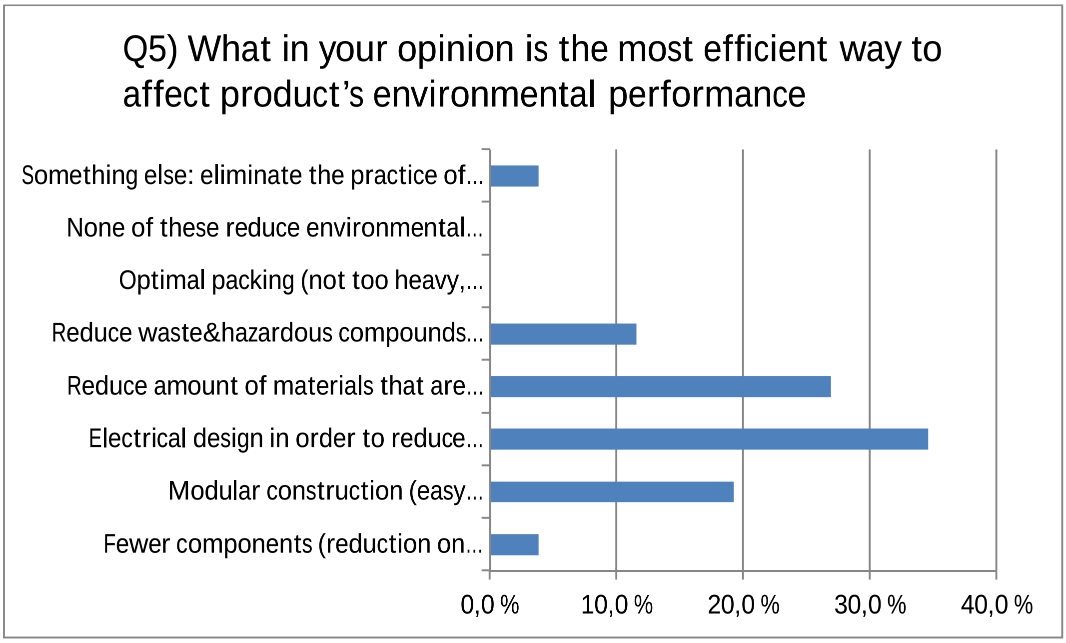


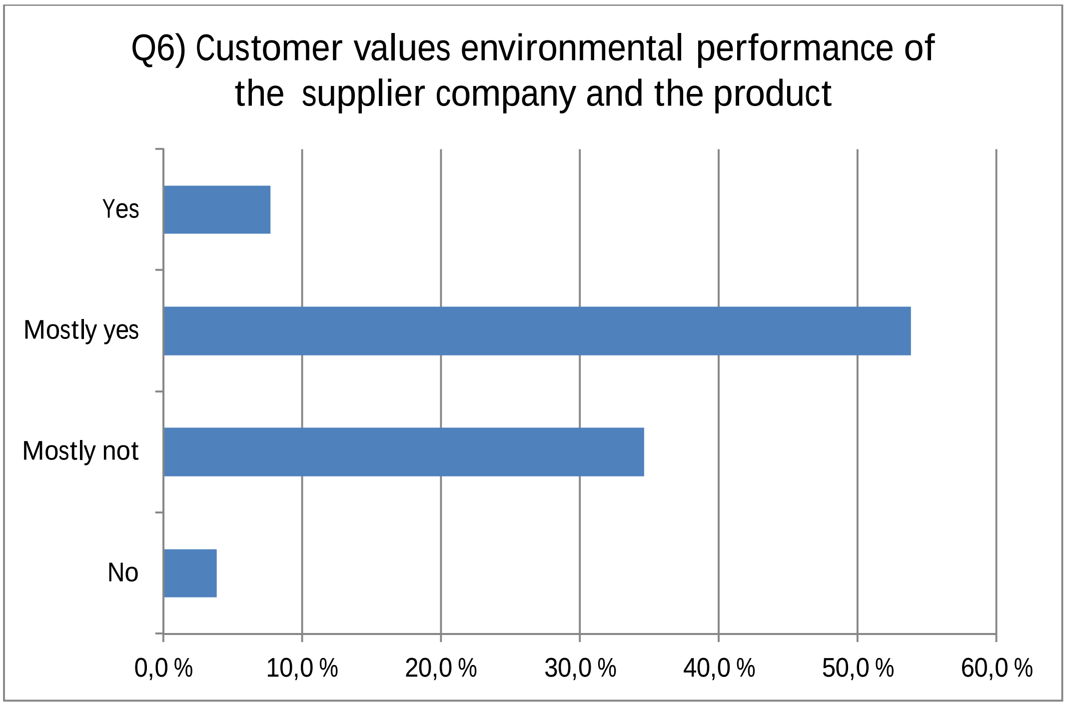
Answers from all of the respondent to question 1.

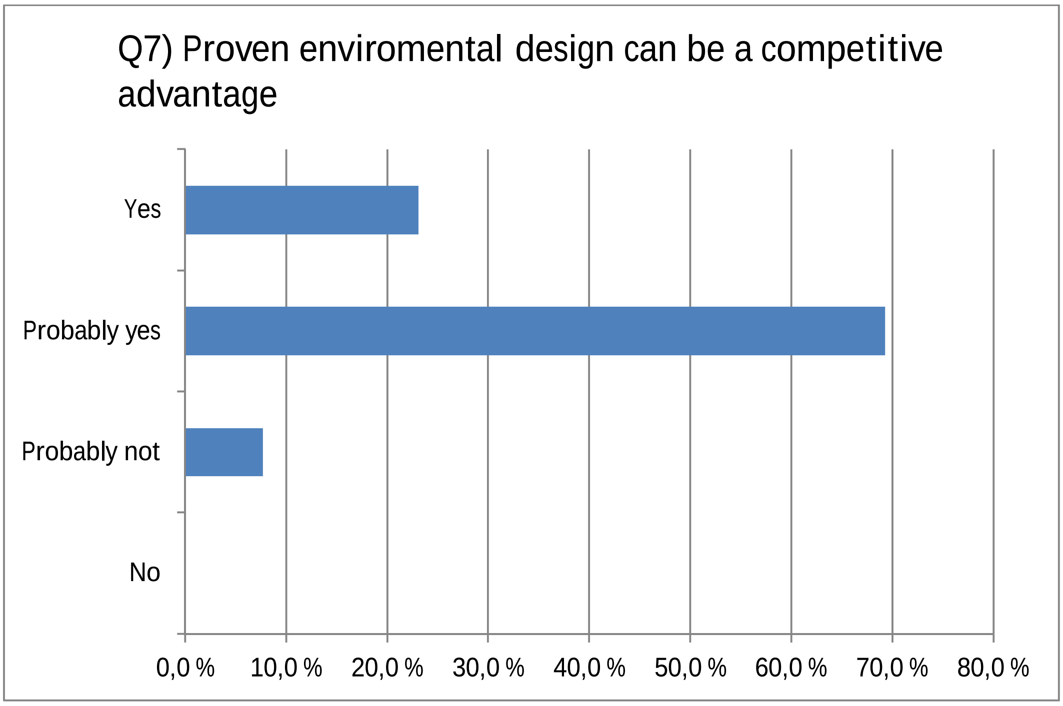


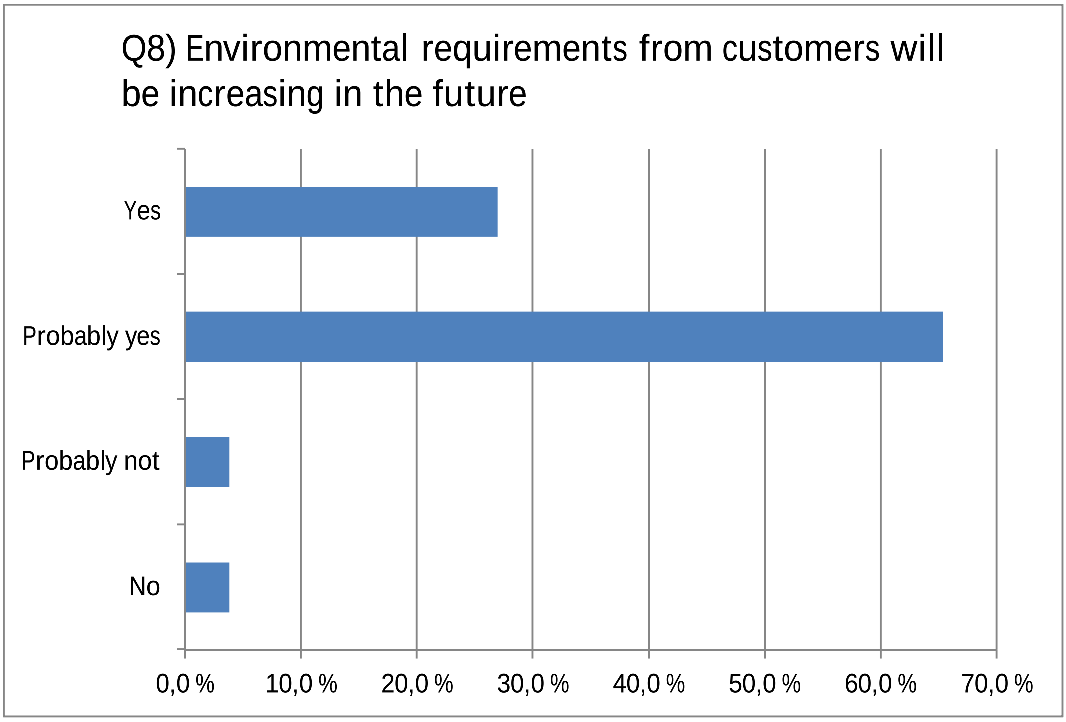

Q3) Do you feel you know enough of ways to affect enviromental performance of the products?
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %

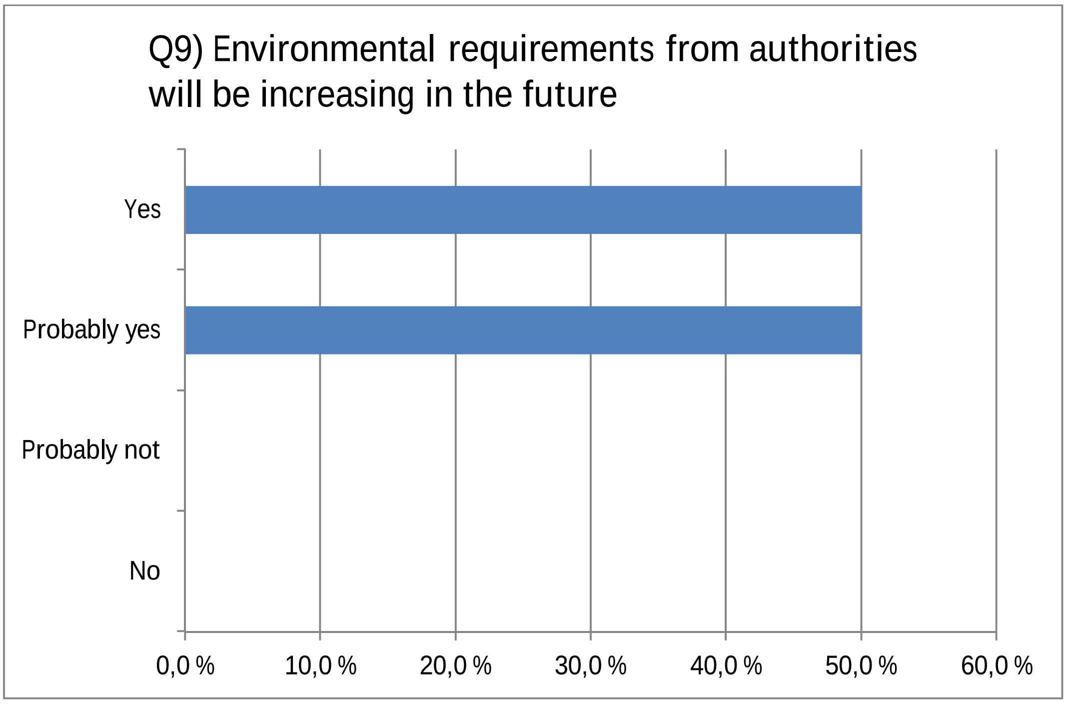

Q4) Do you feel you have enough information on authorities requirements and legislation regarding this product group
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %

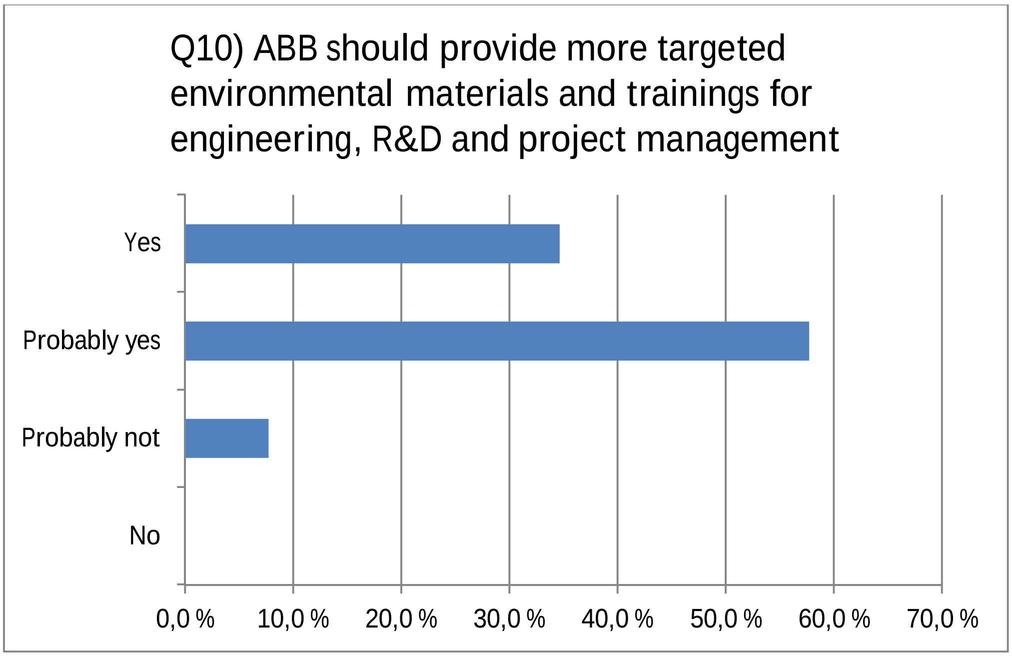

Q5) What in your opinion is the most efficient way to affect product's environmental performance
Something else: eliminate the practice of...
None of these reduce environmental...
Optimal packing (not too heavy,...
Reduce waste&hazardous compounds...
Reduce amount of materials that are...
Electrical design in order to reduce...
Modular construction (easy...
Fewer components (reduction on...
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %

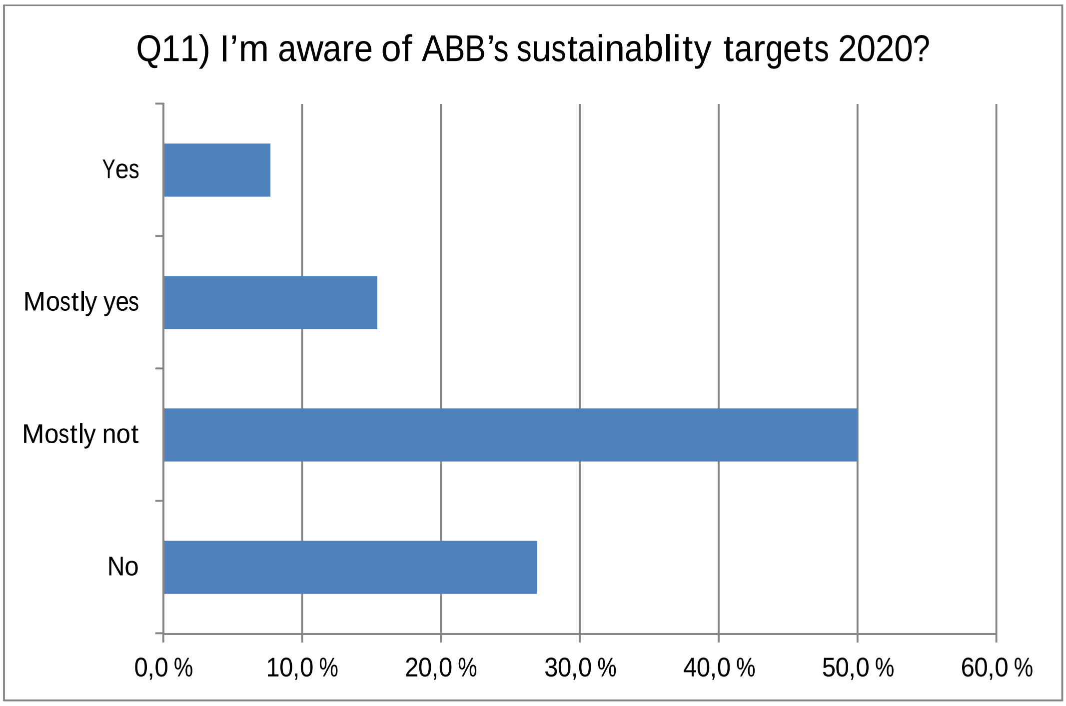

Q6) Customer values environmental performance of the supplier company and the product
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %

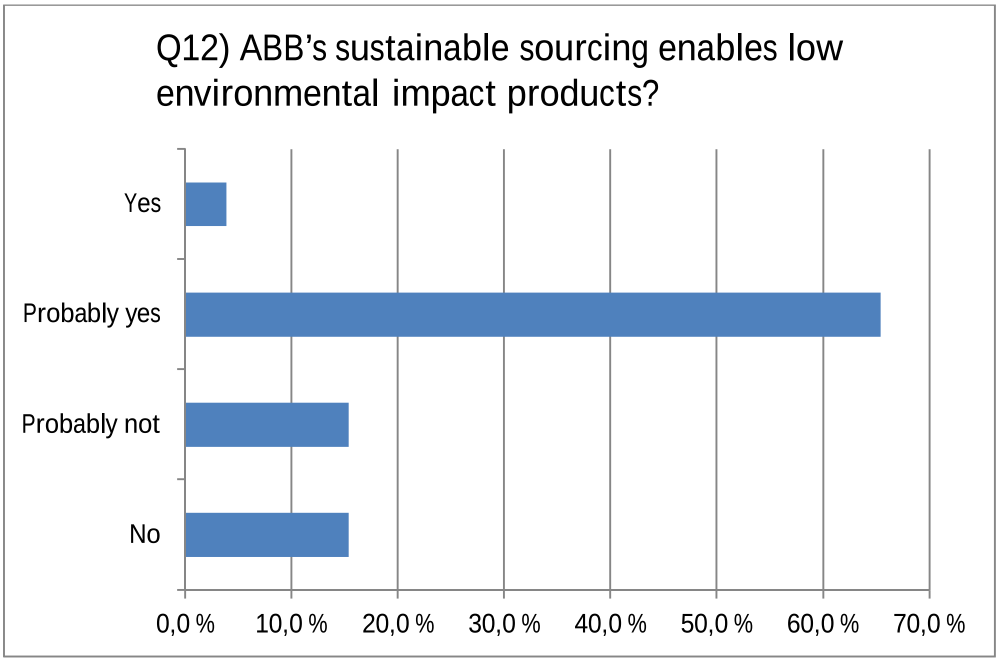

Q7) Proven enviromental design can be a competitive advantage
Yes
Probably yes
Probably not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %
70,0 %
80,0 %

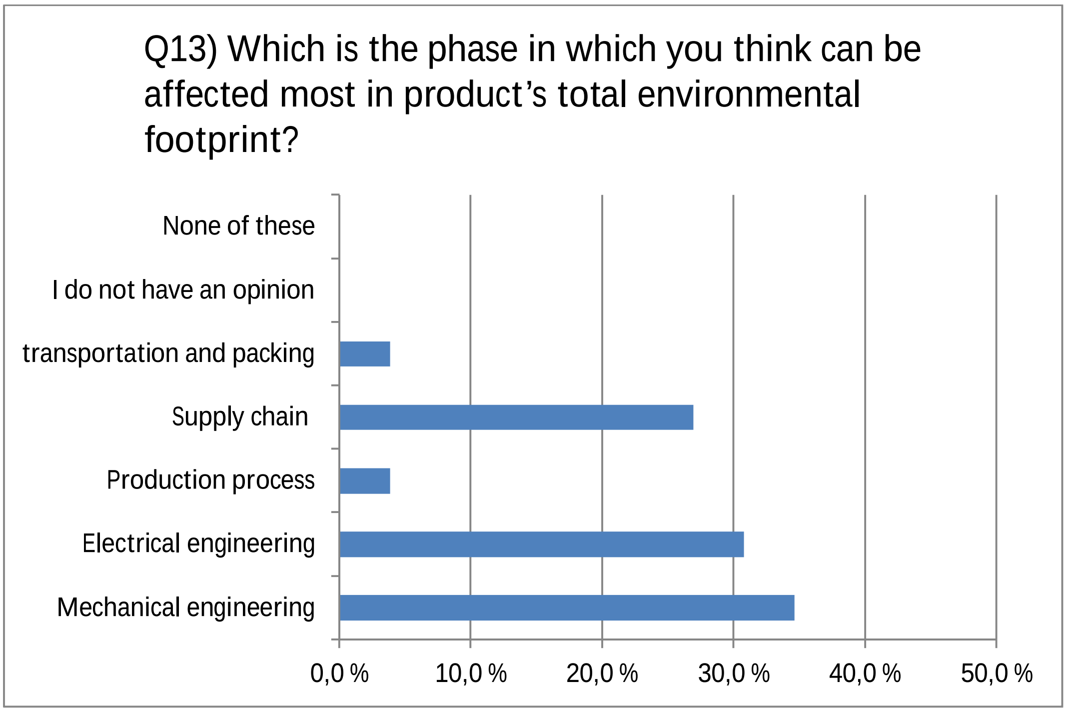

Q8) Environmental requirements from customers will be increasing in the future
Yes
Probably yes
Probably not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %
70,0 %

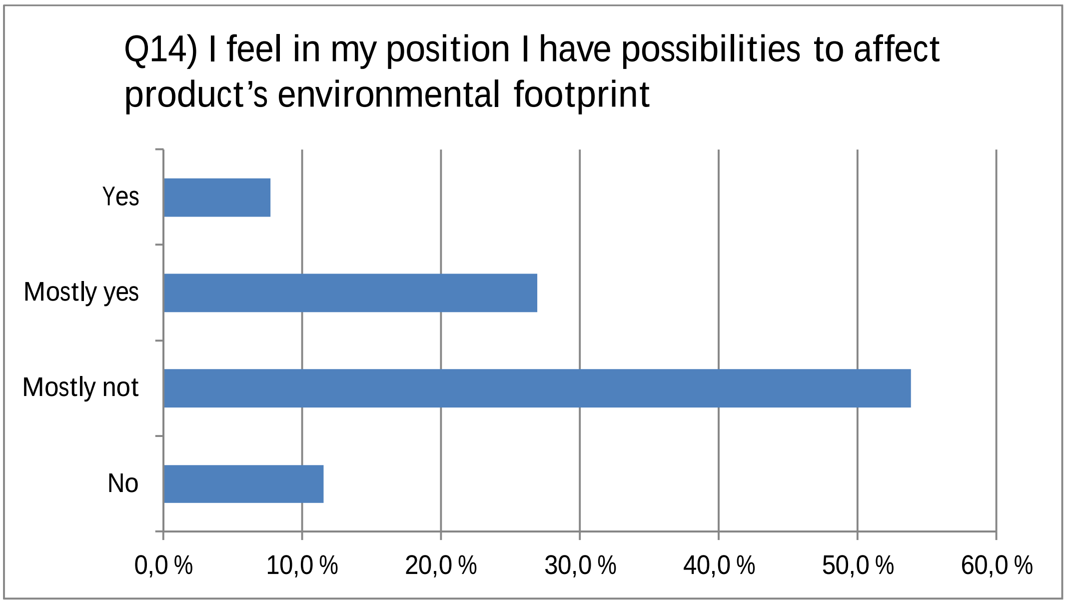

Q9) Environmental requirements from authorities will be increasing in the future
Yes
Probably yes
Probably not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %

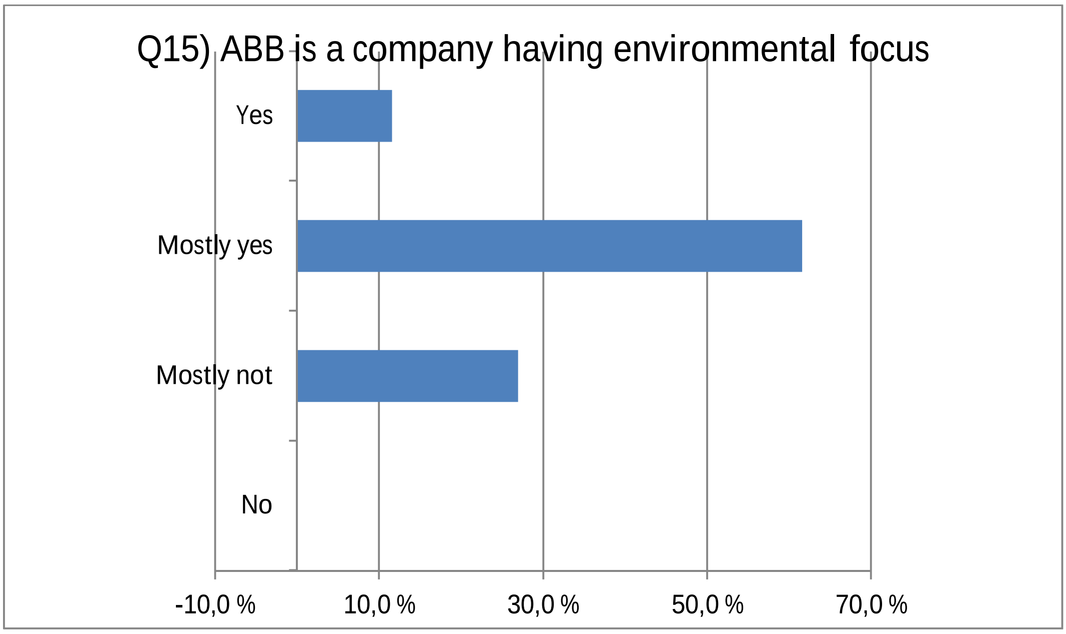

Q10) ABB should provide more targeted environmental materials and trainings for engineering, R&D and project management
Yes
Probably yes
Probably not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %
70,0 %

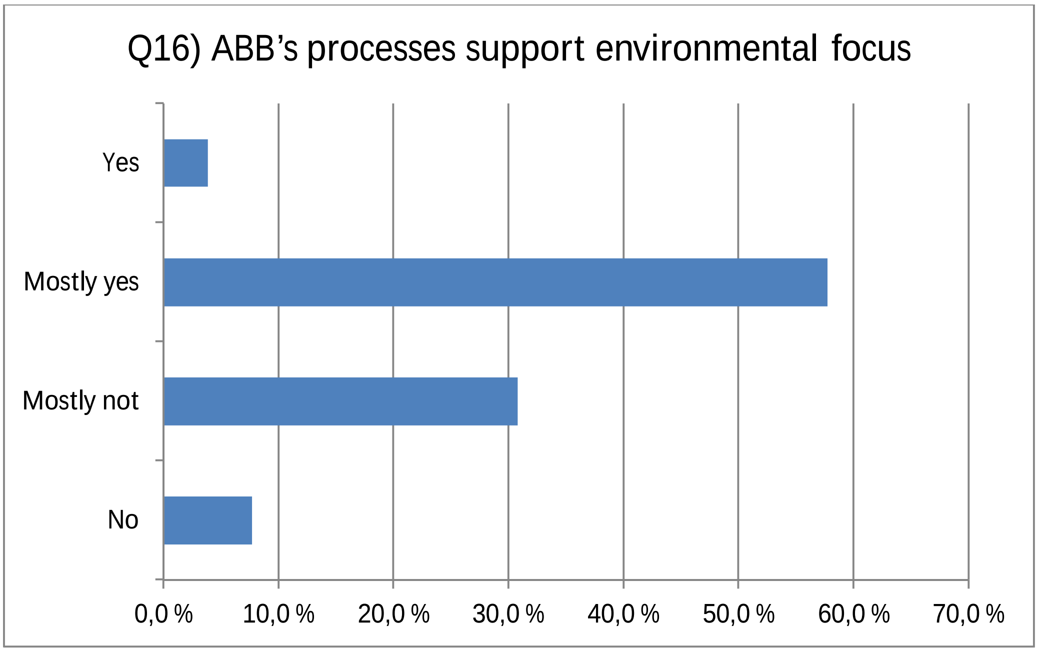

Q11) I'm aware of ABB's sustainablity targets 2020?
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %

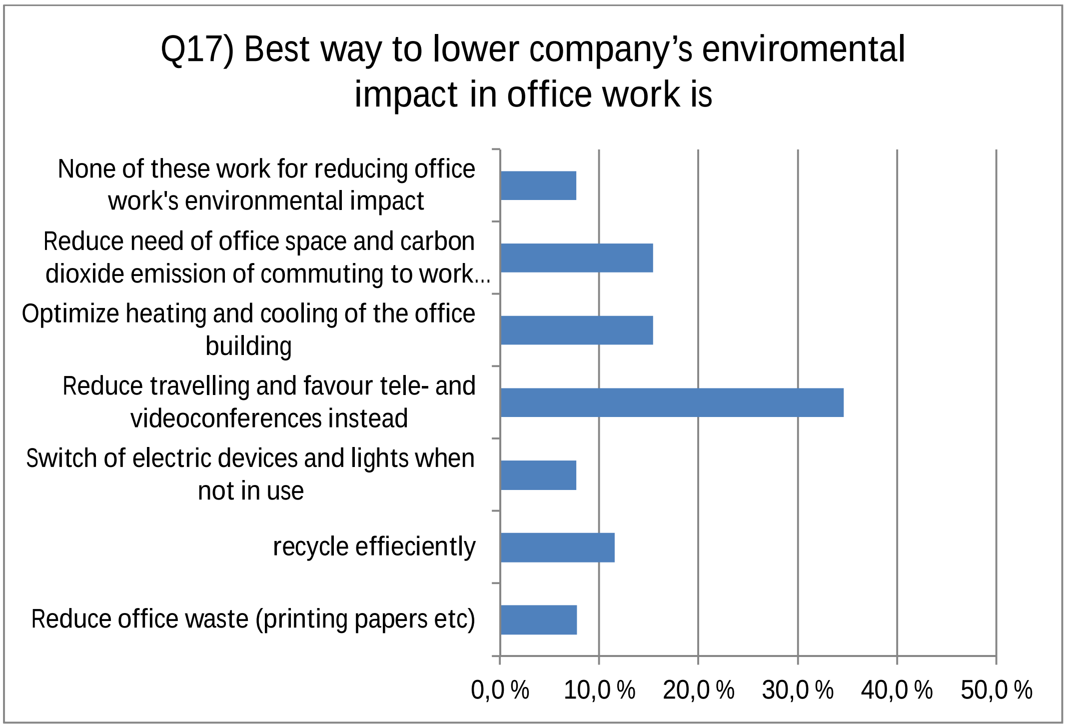

Q12) ABB's sustainable sourcing enables low environmental impact products?
Yes
Probably yes
Probably not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %
70,0 %


Q13) Which is the phase in which you think can be affected most in product's total environmental footprint?
None of these
I do not have an opinion
transportation and packing
Supply chain
Production process
Electrical engineering
Mechanical engineering
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %


Q14) I feel in my position I have possibilities to affect product's environmental footprint
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %


Q15) ABB is a company having environmental focus
Yes
Mostly yes
Mostly not
No
-10,0 %
10,0 %
30,0 %
50,0 %
70,0 %


Q16) ABB's processes support environmental focus
Yes
Mostly yes
Mostly not
No
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %
60,0 %
70,0 %


Q17) Best way to lower company's enviromental impact in office work is
None of these work for reducing office work's environmental impact
Reduce need of office space and carbon dioxide emission of commuting to work...
Optimize heating and cooling of the office building
Reduce travelling and favour tele- and videoconferences instead
Switch of electric devices and lights when not in use
recycle effieciently
Reduce office waste (printing papers etc)
0,0 %
10,0 %
20,0 %
30,0 %
40,0 %
50,0 %

APPENDIX 3. ENVIRONMENTAL AWARENESS SURVEY – EXTERNAL

Time	*Survey recipients*	*Respondents*	*Response percentage*
15 – 27.8.2015	10	3	30%

ABB Power and productivity for a better world™

Environmental awareness and supplier environmental performance survey

Environmental awareness and supplier performance survey- Your feedback to ABB

1) Supplier's environmental performance is a valuable supplier performance indicator?
- no
- probably not
- probably yes
- yes

2) Proven environmental design can be a competitive advantage
- no
- probably not
- probably yes
- yes

3) Environmental requirements from your customers towards you will be increasing in the future
- no
- probably not
- probably yes
- yes

4)Environmental requirements from the authorities and legislation will be increasing in the future
- no
- probably not
- probably yes
- yes

5)Environmental requirements from you to your suppliers (like ABB) will be increasing in the future
- no
- probably not
- probably yes
- yes

6) I'm aware of ABB's sustainability targets 2020
- no
- mostly not
- mostly yes
- yes

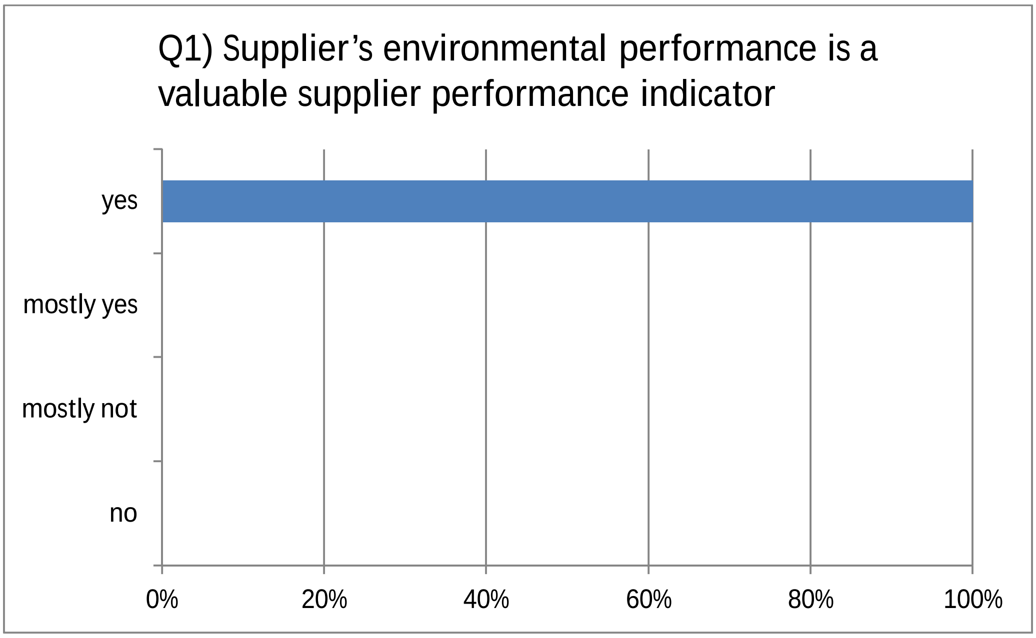
7) ABB's sustainable sourcing enables low environmental impact products
- no
- probably not
- probably yes
- yes
- I do not know

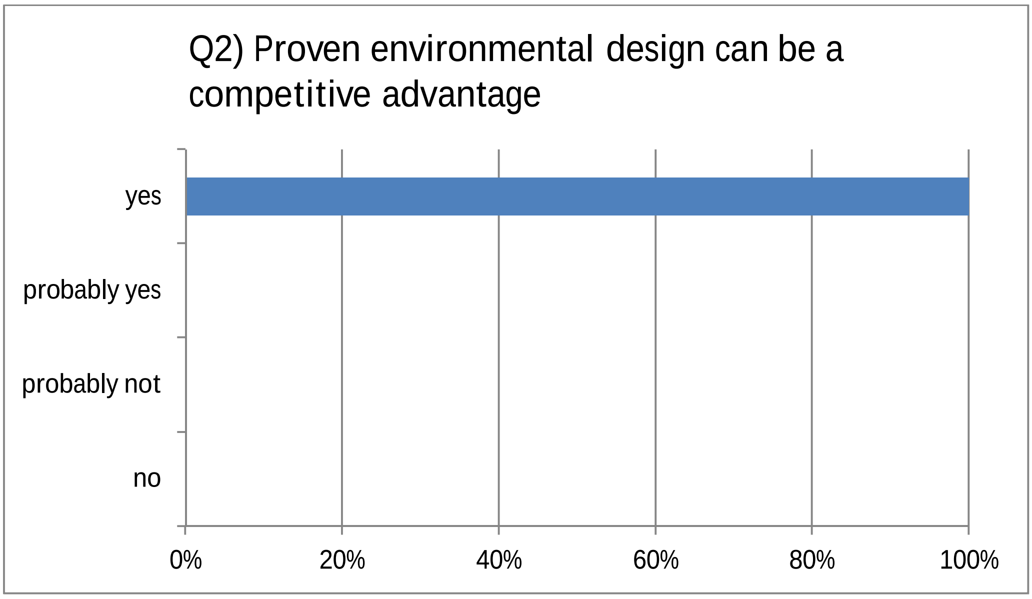
8) ABB is a company having environmental focus
- no
- mostly not
- mostly yes
- yes
- I do not know

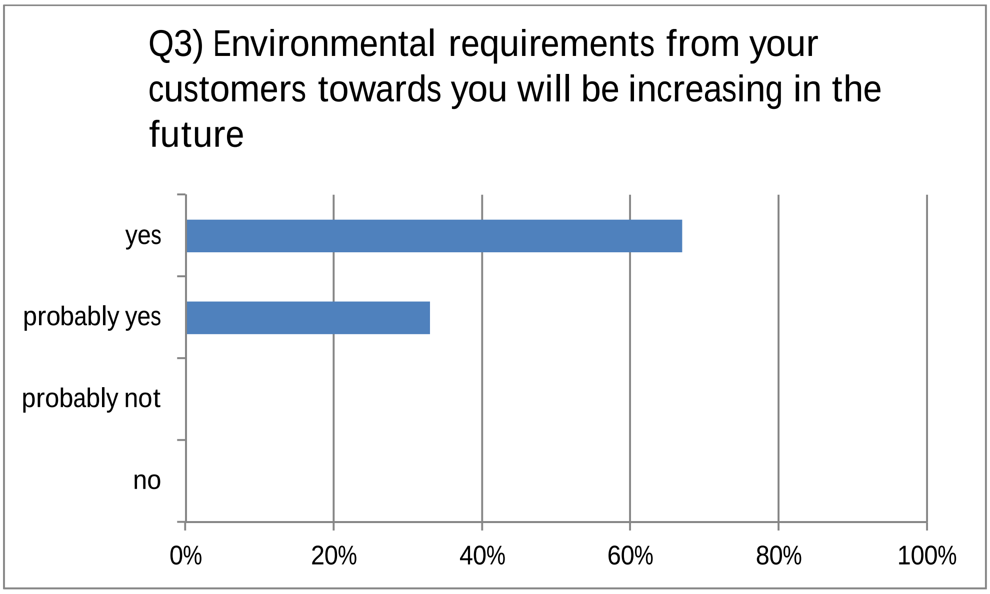
9) ABB's processes support enviromental focus	◯ no ◯ probably not ◯ probably yes ◯ yes ◯ I do not know
10) I get enough information of ABB products environmental performance	◯ no ◯ probably not ◯ probably yes ◯ yes ◯ I do not know
11) Proven environmental design could be valued in product price more than less environmentally friendly	◯ no ◯ probably not ◯ probably yes ◯ yes
12) Our Company asks environmental product declarations from our suppliers (like ABB)	◯ no ◯ in most cases not ◯ in most cases yes ◯ yes
13) Our Company asks our suppliers (like ABB) to answer environmental questions or we ask of environmental performance during our audits	◯ no ◯ in most cases not ◯ in most cases yes ◯ yes
14) What in your opinion is the most efficient way to affect on product's environmental performance (if none of these, you can fill in your suggestion in the end of this questionnary in free form field)	◯ Fewer components (reduction on materials) ◯ Modular construction (easy maintenance, simplier production processes or istallation of component to turbine) ◯ Electrical/mechanical design in order to reduce operating costs over the lifetime ◯ Reduce amount of materials that are hard to reuse, repair or recycle ◯ Optimal packing (not too heavy, recyclable transportation pallets etc) ◯ District use of hazardous materials in product and production process ◯ None of these improve environmental performance of product or process ◯ I have other ideas, what -tell in field 15
15) Any other comments, answers, or feedback on environmental issues:	

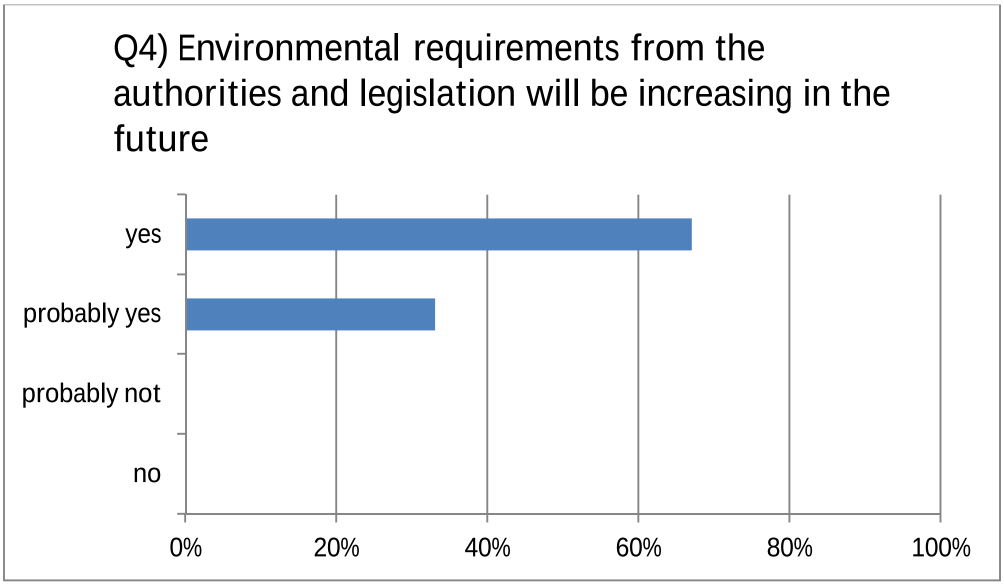
APPENDIX 4. CUSTOMER ENVIRONMENTAL SURVEY RESULTS

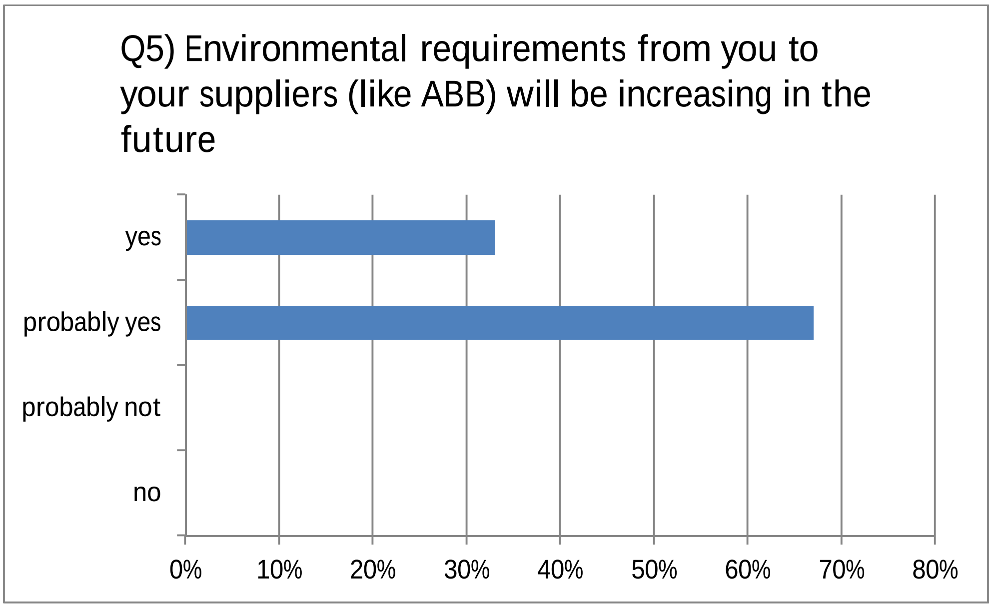
Time	*Survey recipi-ents*	*Respondents*	*Response per-centage*
15 – 27.8.2015	10	3	30%

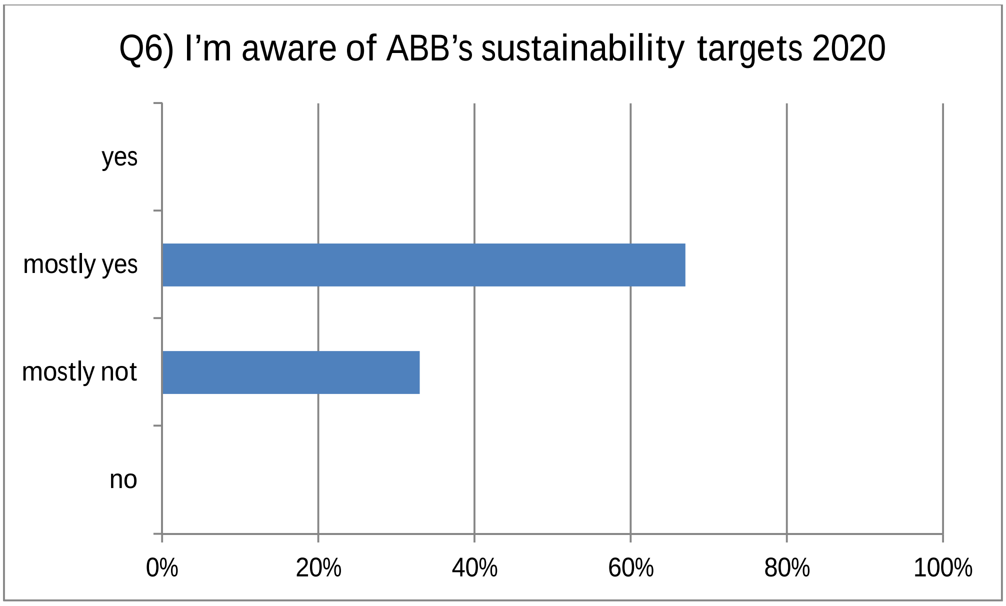


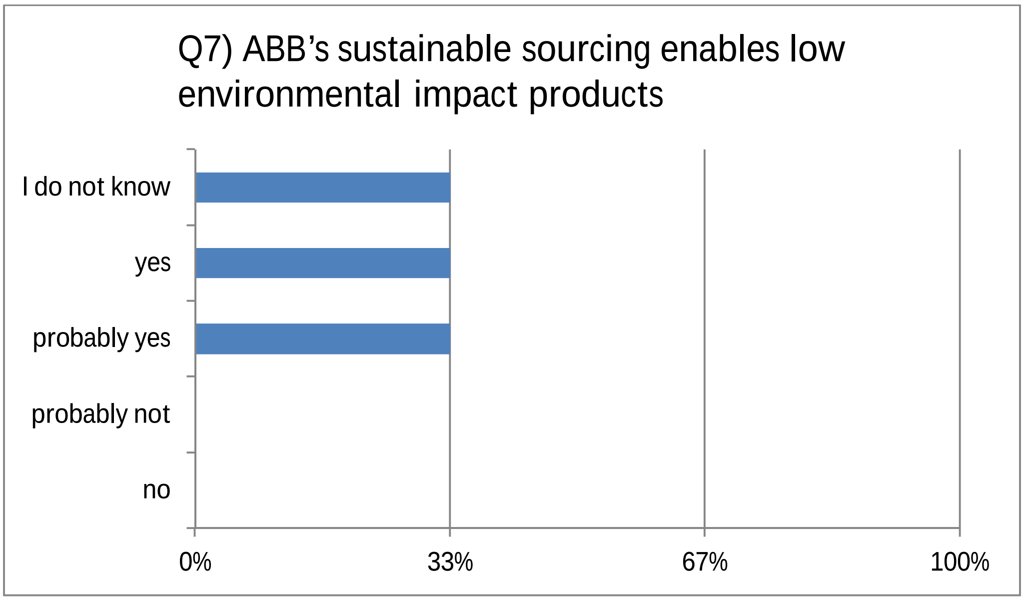


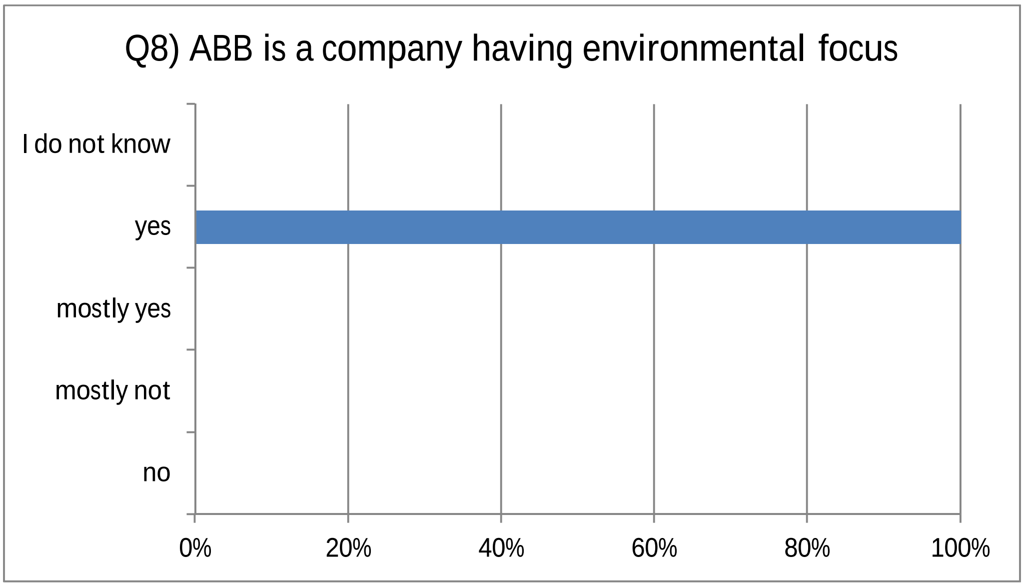

Q3) Environmental requirements from your customers towards you will be increasing in the future
yes
probably yes
probably not
no
0%
20%
40%
60%
80%
100%

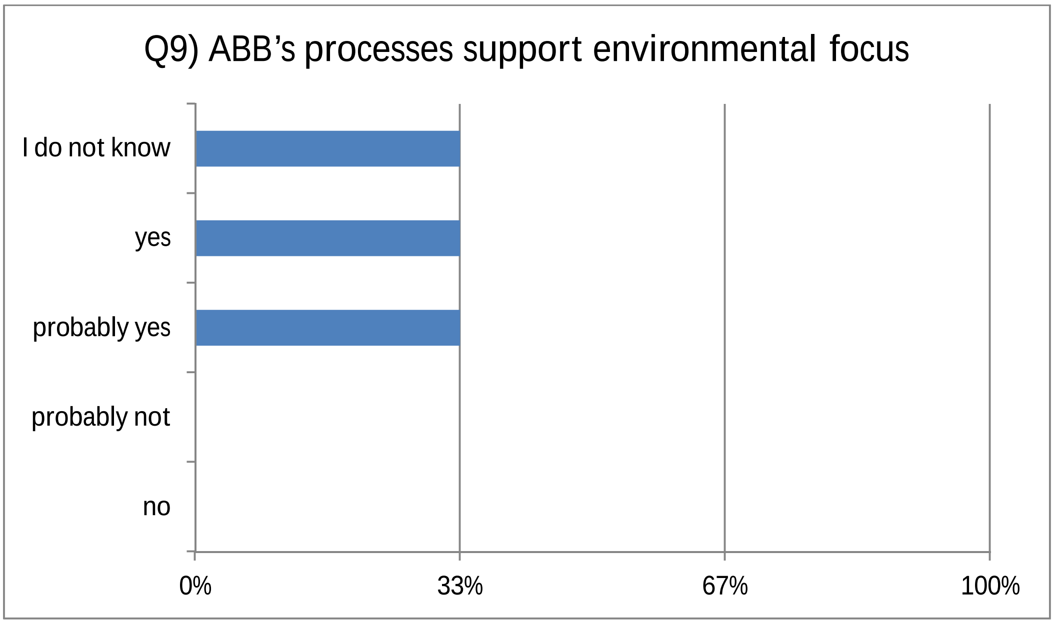

Q4) Environmental requirements from the authorities and legislation will be increasing in the future
yes
probably yes
probably not
no
0%
20%
40%
60%
80%
100%

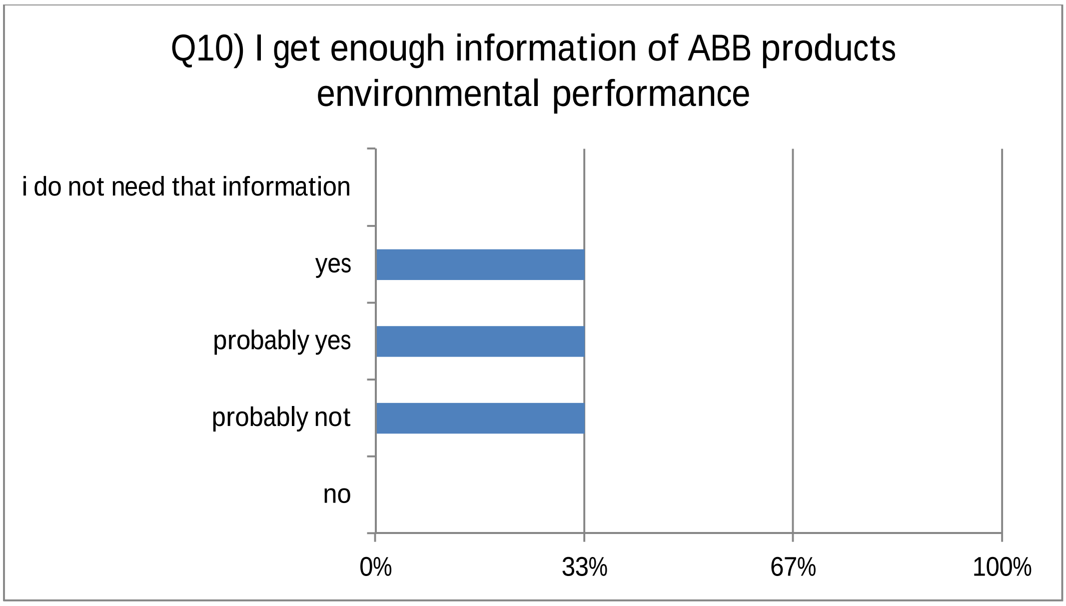

Q5) Environmental requirements from you to your suppliers (like ABB) will be increasing in the future
yes
probably yes
probably not
no
0%
10%
20%
30%
40%
50%
60%
70%
80%

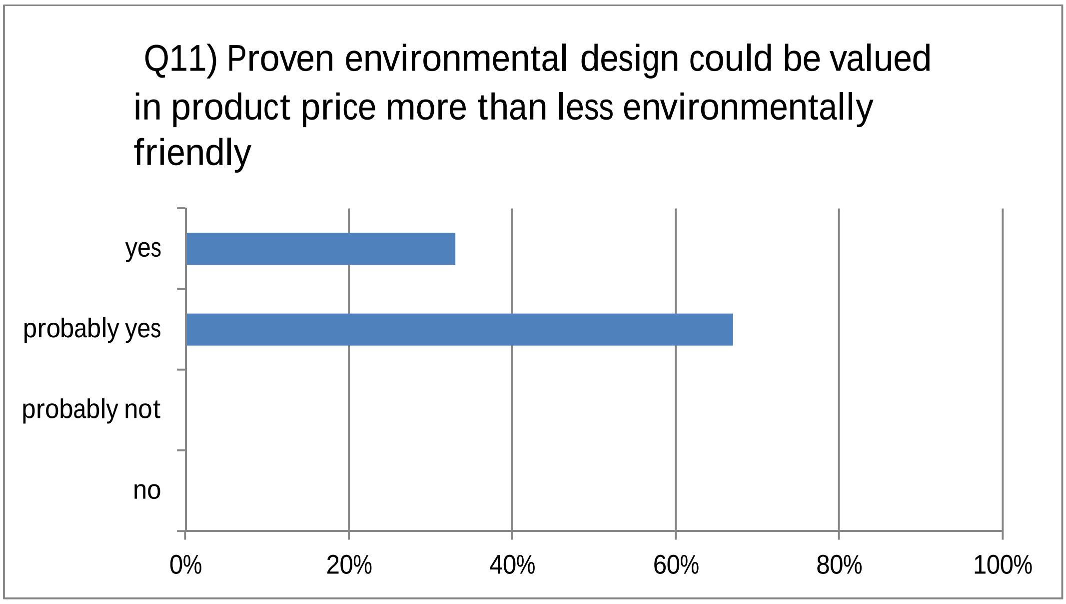

Q6) I'm aware of ABB's sustainability targets 2020
yes
mostly yes
mostly not
no
0%
20%
40%
60%
80%
100%

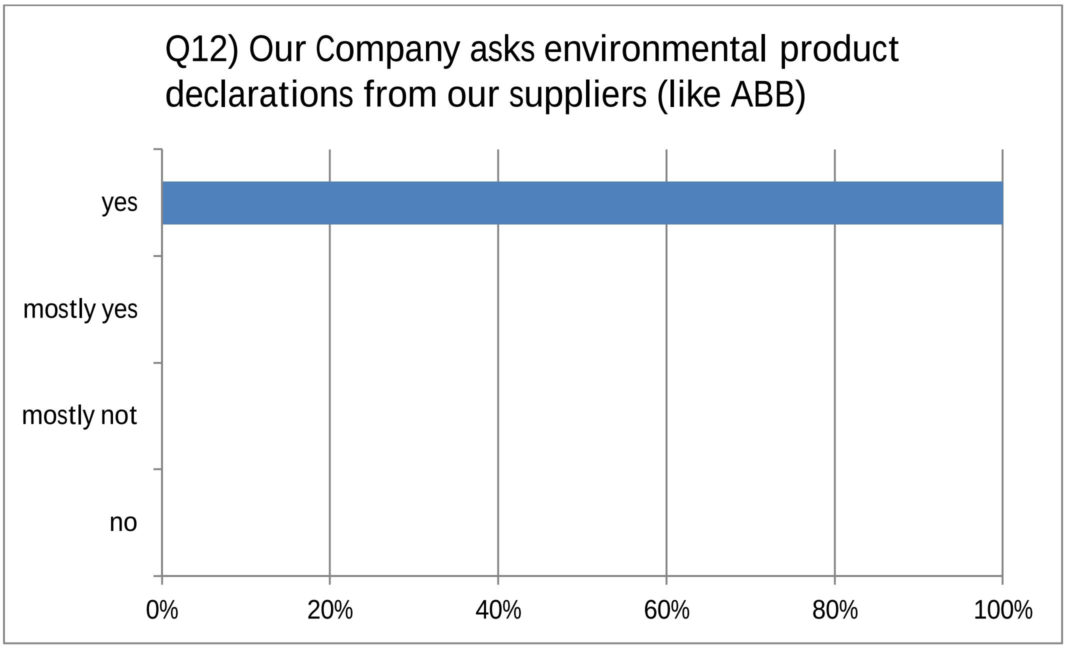

Q7) ABB's sustainable sourcing enables low environmental impact products
I do not know
yes
probably yes
probably not
no
0%
33%
67%
100%

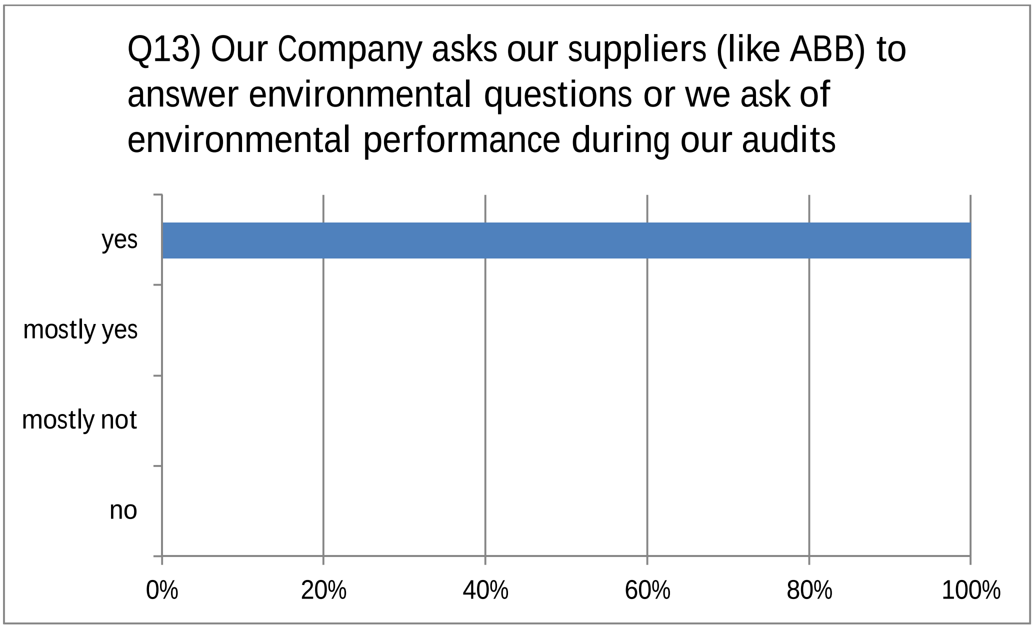

Q8) ABB is a company having environmental focus
I do not know
yes
mostly yes
mostly not
no
0%
20%
40%
60%
80%
100%

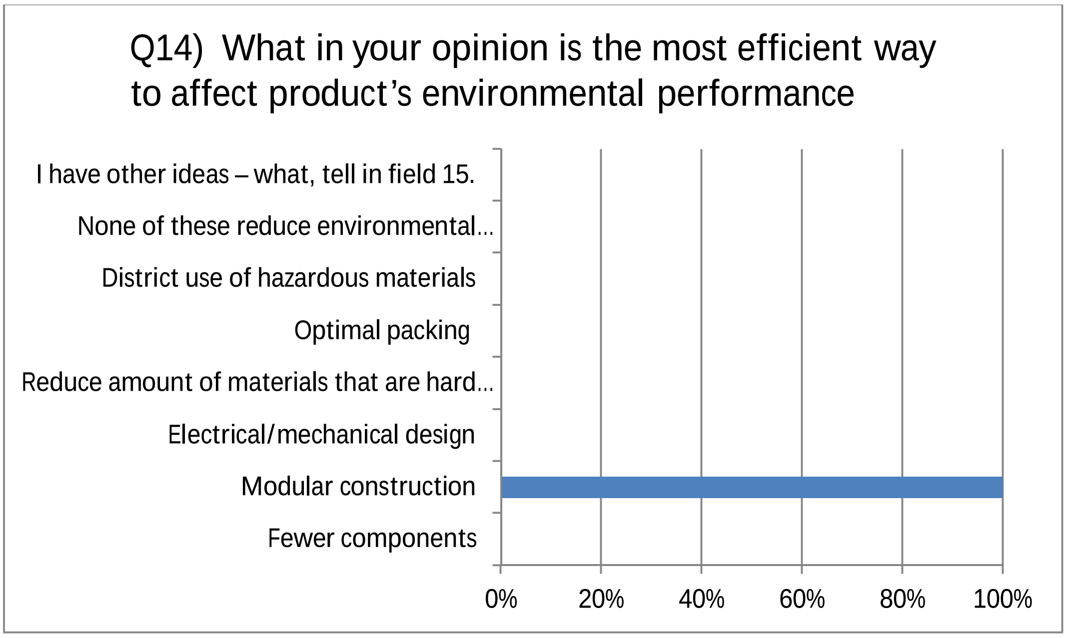

Q9) ABB's processes support environmental focus
I do not know
yes
probably yes
probably not
no
0%
33%
67%
100%


Q10) I get enough information of ABB products environmental performance
i do not need that information
yes
probably yes
probably not
no
0%
33%
67%
100%


Q11) Proven environmental design could be valued in product price more than less environmentally friendly
yes
probably yes
probably not
no
0%
20%
40%
60%
80%
100%


Q12) Our Company asks environmental product declarations from our suppliers (like ABB)
yes
mostly yes
mostly not
no
0%
20%
40%
60%
80%
100%





Q15) any other comments, answers or feedback on environmental issues:

No replies